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Using space technology to save the last wild camels of the Gobi Desert. This is how Liu Shaochuang, a Chinese remote sensing specialist, intends to safeguard the last 1,000 individuals of this endangered species scattered across 200,000 square kilometres of arid plains. The information gathered via satellite will bring crucial insights about the impact of climate change on their habitat and the kind of threats they face. His Rolex Award for Enterprise will support his fieldwork and provide a year's worth of airtime for satellite trackers, which will help him advocate for the creation of two new conservation zones in this vast area between China and Mongolia.

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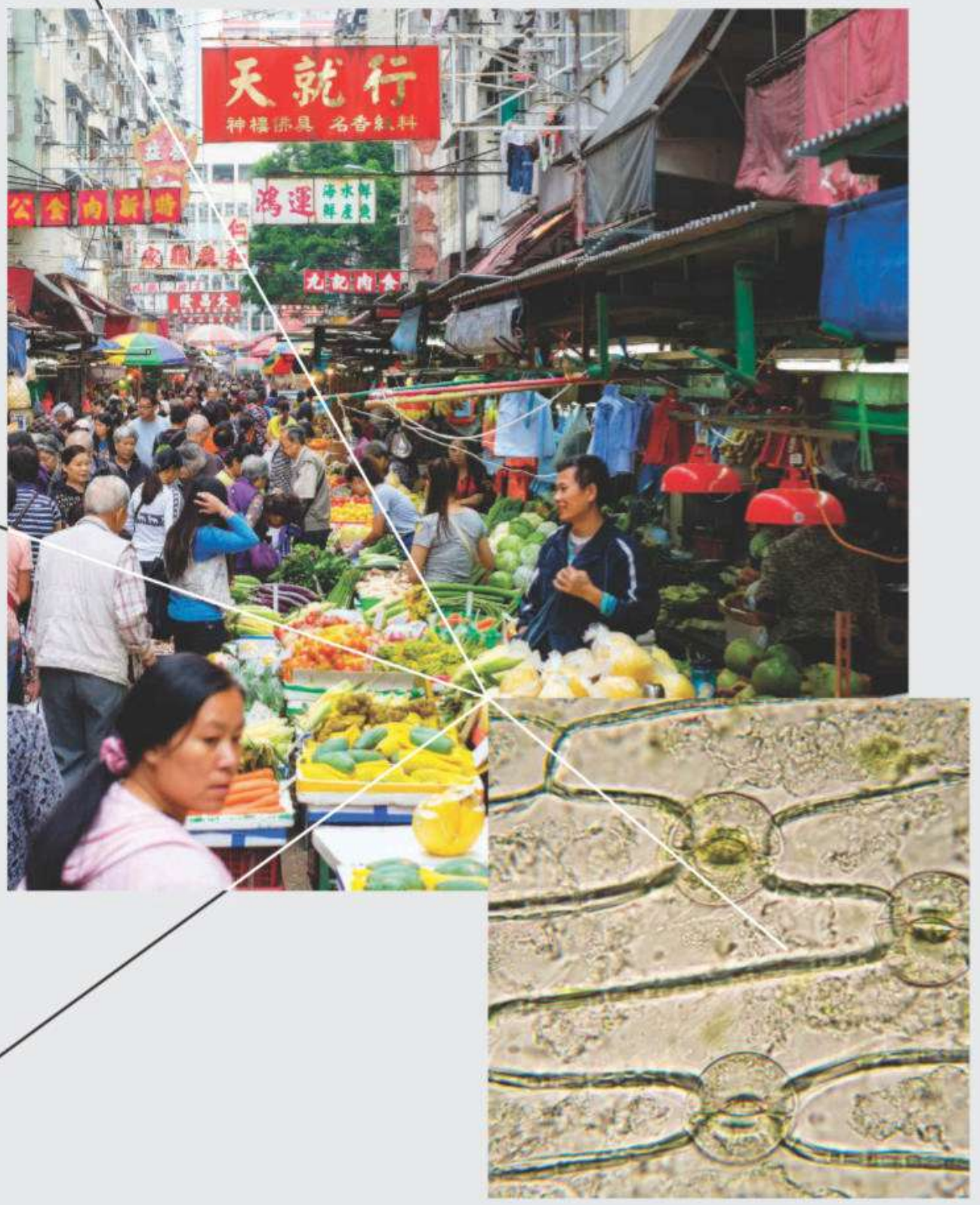

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A radical new approach to stopping the cycle of intrusive thoughts and compulsive habits

New Scientist
BREAKING FREE FROM OCD
A radical new approach to stopping the cycle of intrusive thoughts and compulsive habits

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Cover image: Raymond Biesinger

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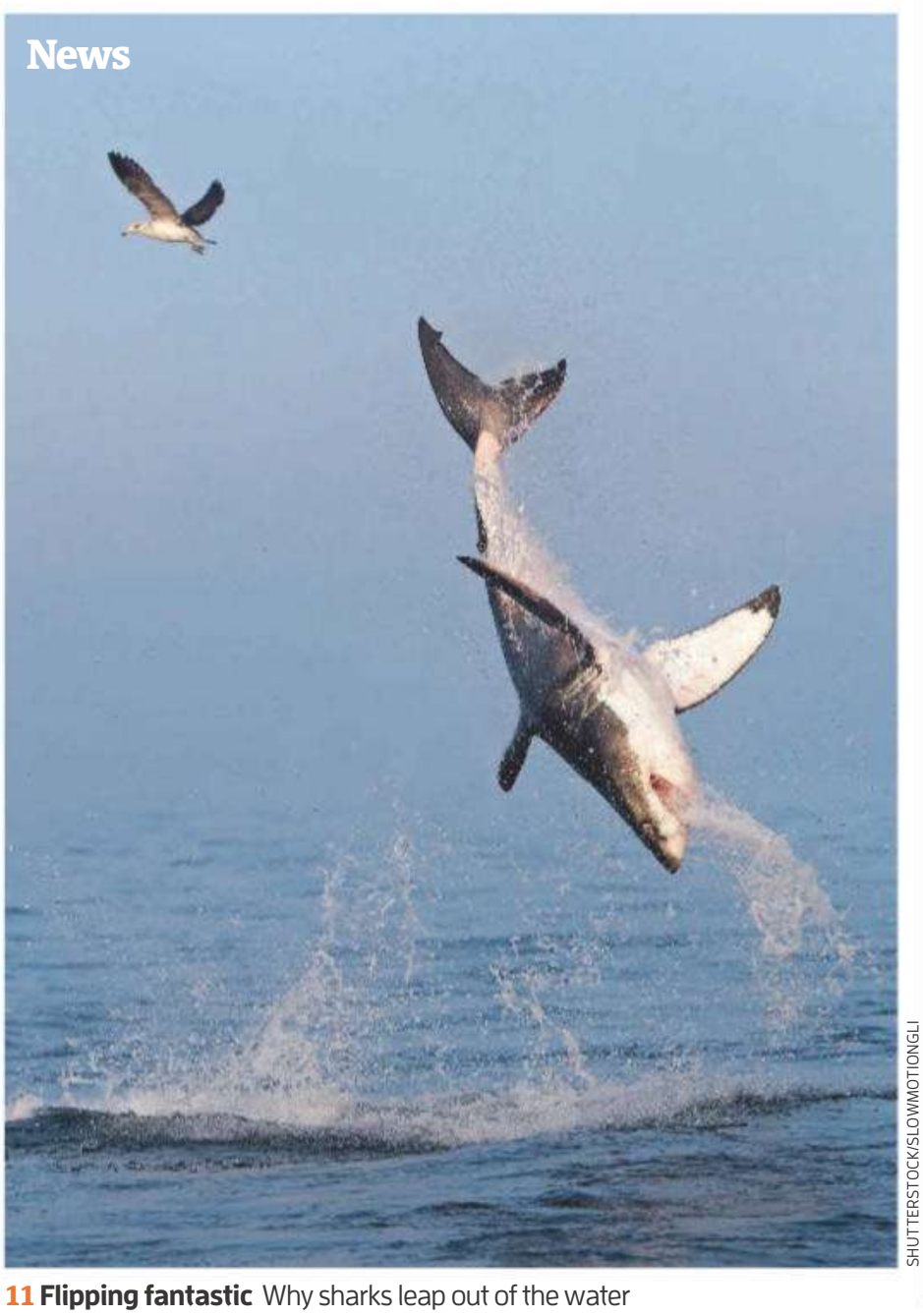

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NS Live

Life, death and disease in the Middle Ages

Hear TV presenter and author Alice Roberts reveal how science is unlocking secrets from the Middle Ages and Renaissance. On 13 October at New Scientist Live, online or in person at London's ExCeL Centre, learn more about the impact of epidemics that swept through Europe in these periods and explore the watery grave of the Mary Rose shipwreck. Plus, learn how archaeogenetic research is uncovering clues about diseases like the plague.

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Tour

The science history and culture of Vienna

Discover a city that, at the turn of the 20th century, was among Europe's most important cultural and academic melting pots. Join psychologist Dany Nobus as you unravel the mind of Sigmund Freud and explore the city in which he spent most of his life. This five-day tour starts on 25 November and costs £2236.

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Podcast

Weekly

The team reveal how researchers have managed to make living mice completely transparent. There is also a promising new blood cancer treatment. Hear why the US military's latest high-tech spy gear is a balloon and why collapsing bat populations are affecting infant mortality in the US. Plus, imagine how dark deep space really is.

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STEPHEN FOOTE/ALAMY

Sunken secrets Find out what happened aboard the Mary Rose

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Puff piece AI gives the Pope a makeover

Video

Spotting deepfakes

Deepfakes, in which a person's facial expression or speech is generated or altered, can be tricky to identify on first glance. Yet their potential to misinform or disrupt democratic processes is concerning. Journalist Andrea Hickerson and computer scientist Edward J. Delp discuss the rising threat from AI-created content and what we can do about it.

youtube.com/newscientist

Newsletter

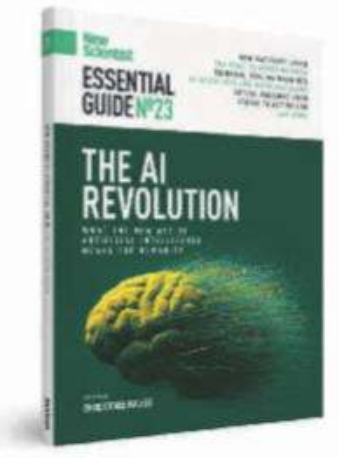
Lost in Space-Time

Mathematician Chris Bernhardt, author of the book *Beautiful Math*, explains the mathematics that enabled the digital revolution. He peeks behind our screens, revealing how information processing and transmission were radically changed with equations – and made today's internet possible.

newscientist.com/lost-in-space-time

Podcast

"They have literally turned a normally opaque animal see-through"



Essential guide

Tools such as ChatGPT have put artificial intelligence on front pages around the world. So why has AI leapt forwards so suddenly? How can generative AI tools help you? And will this tech lead to human extinction? Get the lowdown on all this and more in our new *Essential Guide*, on sale now.

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OCD is no joke

We need to change how we talk about obsessive-compulsive disorder

WE HAVE probably all heard someone say they are "a little bit OCD", perhaps jokily or as a matter of pride, in reference to their meticulous rearrangement of their bookshelves or habit of spending rather too long cleaning their bathroom.

Most of us have a rough idea of what obsessive-compulsive disorder is, but it tends to be viewed as a behavioural quirk. In fact, this condition – characterised by intrusive thoughts and compulsive actions that you can't stop – is debilitating for the 1 to 3 per cent of the global population it affects.

In this light, quips about being "a little bit OCD" risk trivialising a condition that can be every bit as serious as schizophrenia or depression. The misuse of the term might reflect our ignorance about OCD. But as we explore on page 32, we are now discovering more about how it manifests in the brain – with implications for how we think about the condition.

It is true that a degree of obsessiveness and compulsive behaviour is present in all of us. We go back to check that we locked the front door, and we can't stop our mind wandering to a looming stressful event. In fact, many OCD symptoms seem to represent distortions of useful behaviours. But imagine if the intrusive thoughts and urges to take action didn't stop? That is what characterises OCD.

"We are learning that OCD is a complex condition, with the immune system playing a part"

Thanks to decades of research into the underlying mechanisms behind the condition, we now know that entire brain networks are affected, with significant imbalances in the neurotransmitters that drive the transmission of signals around them. We are also learning that it is a more complex condition than we thought, with the immune system and perhaps even microbes in the gut playing a part.

These insights into the drivers of OCD in the body and brain are opening the way to new treatments, which are sorely needed for those who don't respond to the current first-line therapies. What is abundantly clear, however, is that OCD is a profoundly distressing condition that we are just beginning to get to grips with. It is past time we stopped with the quips. ▮

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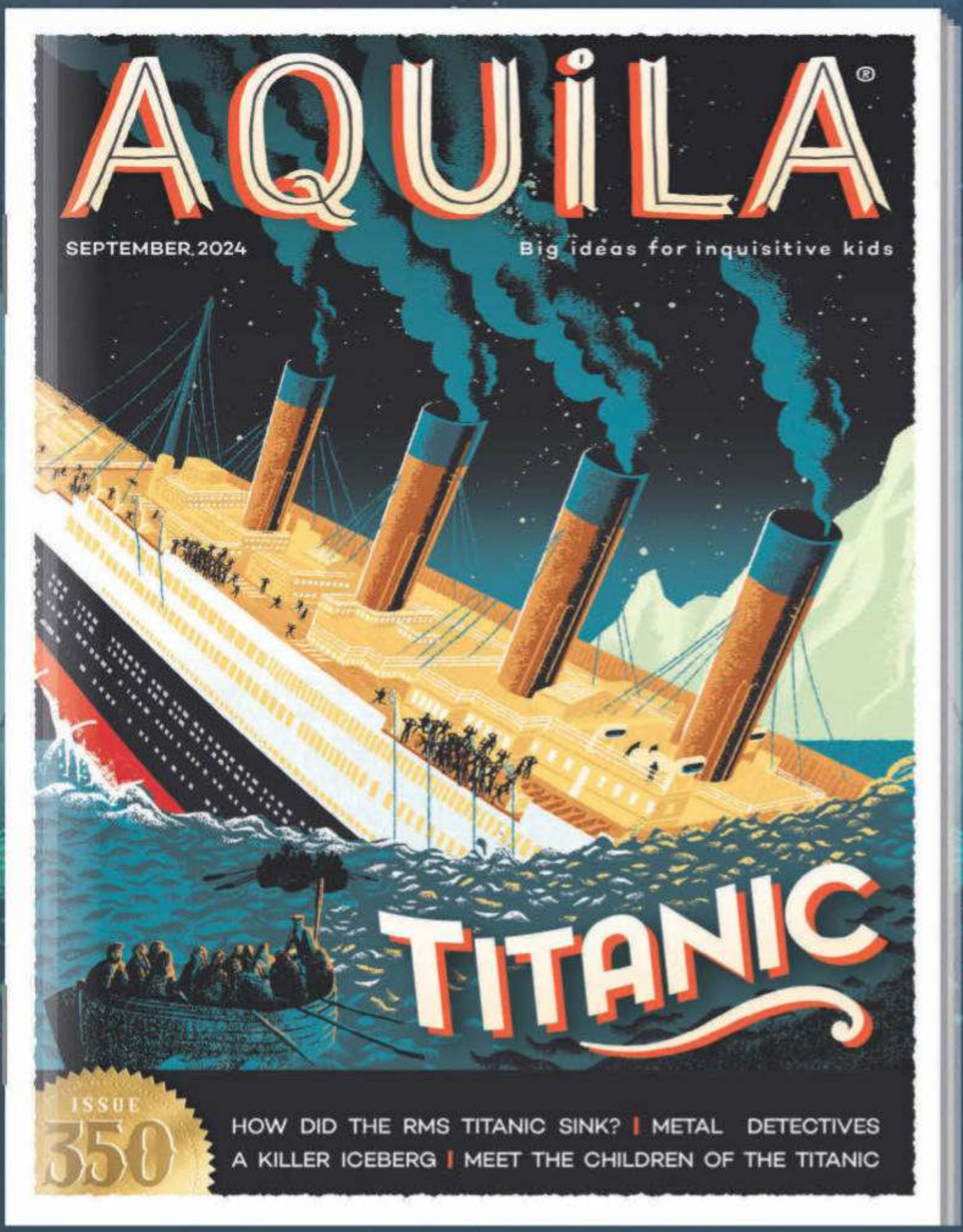
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Strangely quiet
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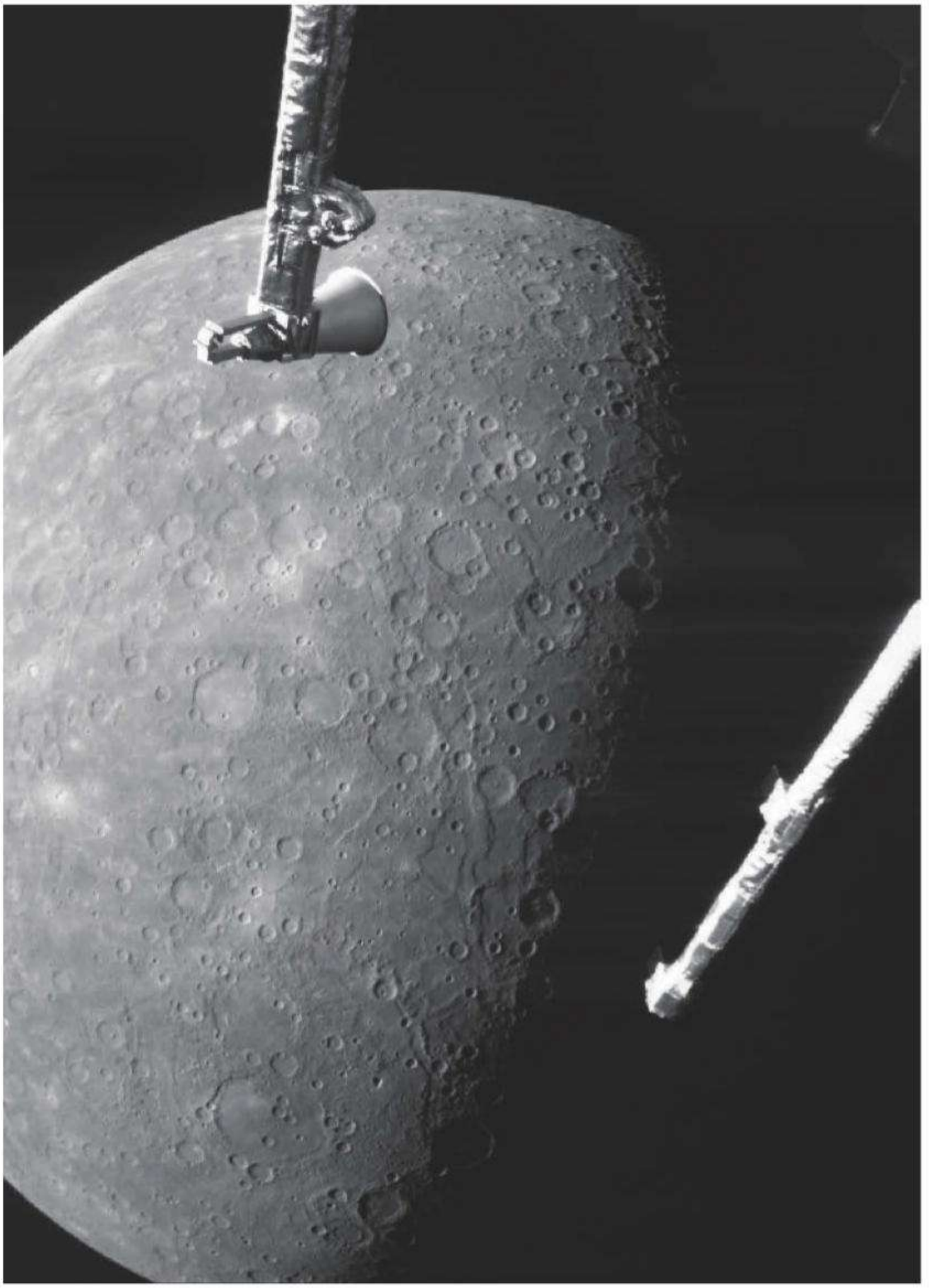


ESA

Space

Getting up close with Mercury

This amazingly clear shot of Mercury was taken by the BepiColombo mission on 5 September as it was 3459 kilometres from the surface of the first planet from the sun. It caught a glimpse of the south pole (on the edge of darkness in the top right of the image). The European Space Agency and Japan Aerospace Exploration Agency probe is using Mercury's gravity to change course, with the goal of entering orbit around it in 2026.

Environment

Why has the Atlantic hurricane season been suspiciously quiet so far?

Madeleine Cuff

FOR the past 27 years, without fail, the Labor Day holiday weekend in the US has featured a storm in the Atlantic – but not in 2024. In early September, the Atlantic basin remained oddly calm, continuing a run of calm weather that has lingered since Hurricane Ernesto whipped through the Caribbean in mid-August.

Forecasters were almost certain that this year would see a busy hurricane season in the Atlantic, says Phil Klotzbach at Colorado State University, who co-authors the institution's influential hurricane forecasts.

Waters in the equatorial Pacific are cooling, marking a global shift to a La Niña weather pattern, which generally favours a more active hurricane season. The Atlantic Ocean is also experiencing near-record levels of heat, providing fuel for developing storms. Against that backdrop, delivering a forecast for a busy season was "like shooting fish in a barrel, super straightforward", says Klotzbach.

In June, Colorado State University issued an aggressive forecast, says Klotzbach, predicting 25 named storms and 12 hurricanes for the 2024 season. In May, the National Oceanic and Atmospheric Administration in the US predicted between 17 and 25 named storms and up to 13 hurricanes.

But so far this season, which is now almost halfway through, only three hurricanes have appeared: Beryl, Debby and Ernesto, plus two named storms below hurricane status, Alberto and Chris. As *New Scientist* went to press, there were hints that a sixth storm, Francine, was on the way. Where have most of the storms gone?

The building blocks of a busy storm season – a transition to La Niña and a warm ocean – are still there, says Klotzbach, but the system isn't doing as expected. "A lot of the stuff we expect has been there, it just hasn't produced the storms. That's more the surprise."

BRANDON BELL/GETTY IMAGES

Damage in Texas from Hurricane Beryl, which hit in July

A few factors are at play. Despite ocean temperatures across the Atlantic basin persisting at near-record highs, one stretch of water near the equator has cooled rapidly to below-average levels. That may have helped push the West African monsoon further north than usual, says Klotzbach, bringing heavy rain to parts of the Sahara desert that normally stay hot and dry.

"This is a very unusual pattern," says Alex Da Silva at forecasting service AccuWeather. The result is that tropical waves, the seedlings of storms, are being pushed off the north-west coast of Africa far further north than normal, over the colder waters of Western Sahara. "That tends to squelch your storms," says Klotzbach.

Tropical waves travelling over the Sahara are also picking up dusty, dry air. On 3 September, the European Union's climate service Copernicus said easterly winds have blown significant amounts of Saharan dust into the eastern Atlantic. "For hurricanes to develop, you need moisture," says Ben Kirtman at the University of Miami in Florida. "This deep layer of dry air coming off Africa into the Atlantic prevents the storms from really kicking off."

There are other reasons too. Although La Niña is developing, it hasn't happened as fast as expected, says Da Silva, so the wind conditions haven't been as suited to creating hurricanes as forecasters thought.

Meanwhile, a weather pattern known as the Madden-Julian oscillation has brought dry weather over the Atlantic since late August, says Kirtman. The oscillation has "fully enveloped into the Atlantic now", he says, suppressing storm activity.

"It's definitely weird," says Klotzbach. "Everything looks kind of anaemic out there."

The Atlantic hurricane season reaches its peak around 10 September – after *New Scientist* goes to press – so forecasters say it is too early to declare the season an anticlimax. The progression towards La Niña is picking up pace, creating the right conditions for storm formation. Meanwhile, ocean waters, particularly around the eastern US coast, remain extremely warm. That lays the groundwork for storms to rapidly intensify once they do develop, says Da Silva.

"I'm concerned that the second half of the season could ramp up," he says. "The warm waters are still there – if anything, they are warmer than when Beryl went through. So it's just going to take one storm to come through there... and we could be looking at another major hurricane."

The changing climate escalates this risk. While it is still unclear if a warming world will produce more storms, research shows that it increases the chances of hurricanes rapidly intensifying, leaving communities with little warning. Climate change can increase the volume of rain dumped by a storm and the severity of storm surges, raising the risk of floods.

"Even if this season is not yet quite as active as we thought, as we warm the planet we are still stacking the deck for the possibility of a hurricane to be very intense," says Andra Garner at Rowan University in New Jersey. ▮

5

Named storms since 1 June, the start of the Atlantic season

17 to 25

Named storms predicted for this season, ending 30 November

New Scientist Live

Have we been predicting the climate all wrong?

See David Stainforth argue for a different approach

newscientist.com/nslmag

Forensic science

Smart speakers could help crack crimes

Information on recognised faces and internet searches can be extracted from an Amazon Echo

Matthew Sparkes

POLICE can access a trove of data from smart speakers found at crime scenes that could be invaluable in solving murders or burglaries. Data on recently recognised faces, internet searches and voice commands could be extracted even without the owner's permission or assistance from the manufacturer.

Jona Crasselt and Gaston Pugliese at the University of Erlangen-Nuremberg in Germany tested how much information can be pulled from such a device after seeing news coverage of Amazon refusing police access to smart speaker data in a murder case.

"We not only obtained access to the local data, but also were able to access the data stored in the cloud," says Pugliese. "Forensic investigators would be able to access the data themselves without relying on Amazon to provide it to them."

The researchers focused on Amazon's Echo Show 15, a smart assistant with a display screen, a camera, six microphones and an ambient light sensor. They probed inside the Echo Show with a device designed to test what signals or data are flowing at various points on a circuit board. The pair were able to gain access to the unencrypted file system, revealing logs of detected movement and faces recognised by the built-in camera and artificial intelligence.

In this file system, they also found a "refresh token", which is used to access data stored in the cloud. This was encrypted, but with a key found elsewhere on the device in an unencrypted file and information gleaned from open-source code published online, they were able to decrypt the token and access anything that the device was authorised to access. This revealed details of voice requests, calendars, contacts, conversations, photos and videos (arXiv, doi.org/ngdv).

"It requires some technical knowledge to obtain the local data, but it was surprising that the file system was not encrypted," says Pugliese. "It's the common cat-and-mouse game in security research," he says, as hacks are worked out and vendors then change things to secure devices.

An Amazon spokesperson told *New Scientist*: "The security of our devices and customer data is a top priority. In this case, the researcher's findings required direct physical access to the Echo device and specialised expertise to extract data from internal device components. We appreciate the work the security research community does to help us further improve our devices."

Criminologist David Wilson at Birmingham City University, UK, says the use of technology in murder investigations is far less prevalent than crime dramas suggest: less than 2 per cent of murder trials rely on DNA evidence, for example.

"It's a simple human reality that you're most likely to be murdered by someone you know," says Wilson. "We already have access to information from those domestic settings through mobile phones, Facebook, Instagram posts."

While smart speaker evidence may be useful, there is a trade-off, he says. "I think it's right that Amazon would be a bit reluctant to release that information because there are privacy issues." ▮

Marine biology

The many reasons sharks take a leap out of the water

SHARKS and rays jump out of the water for a variety of reasons, including courtship, birthing and hygiene, and the behaviour is more common than previously thought.

Breaching has been reported among fast-swimming predatory sharks – such as great whites (*Carcharodon carcharias*) – as well as filter-feeding basking sharks (*Cetorhinus maximus*) and many species of ray, including manta rays.

"Anyone who witnesses a breaching animal, be it a shark, ray or whale, should think of why they perform this acrobatic behaviour," says Peter Klimley at the University of California, Davis.

Reviewing the scientific evidence, Klimley and his colleagues have found that studies have proposed a range of possible functions for breaching. The action could be a way of cleaning, dislodging external parasites, clearing gills, ejecting faeces or internal parasites, or to aid birthing, the researchers found. Breaching is also observed when a predator tries to chase, herd or stun its prey, or avoid a threat.

SERGEY URYADNIKOV/ALAMY

A great white shark breaching ready to attack prey

The analysis, the first to look at breaching across sharks and rays as a group, suggests there is no single reason for this highly specialised behaviour because the lifestyle of each species is so different.

Breaches often take place during courtship rituals and researchers suggest the sound could be used for communication (*Environmental Biology of Fishes*, doi.org/ngd8).

"The idea that sharks and rays might communicate with each other over long distances using splashes and breaches is particularly intriguing," says co-author Guy Stevens at the Manta Trust, a UK charity. ▮

Melissa Hobson

New Scientist Live

A talk on the wild side

Hear wildlife presenter Chantelle Lindsay on 12 October

newscientist.com/nslmag

Health

Sweat monitor reveals if you are exercising too hard

Michael Le Page

ELASTIC bands embedded with colour-changing sensors can tell how hard muscles are working by measuring the acidity of your sweat.

The device could be used to improve worker safety in physically demanding jobs, such as the construction industry, as well as to help sportspeople optimise their training, says John Rogers at Northwestern University in Illinois.

"If you see your pH dropping down to very low levels, it'd be a good idea to stop working out," says Rogers. "Otherwise you end up with sore muscles. But it'll also tell you if you haven't worked out enough."

During high-intensity exercise, muscles produce a chemical called lactate. With continued exercise, levels of this in the blood start to shoot up as people near their limits of physical endurance. This can lead to a burning sensation in muscles, sudden loss of energy and extreme fatigue. The fitter people are, the longer and harder they can exercise before blood lactate gets high.

Rogers and his team have come up with an elastic band with a series of tiny reservoirs that fill with sweat at different intervals. Inside each reservoir is a sensor that changes colour depending on things such the concentration of lactate or the acidity of sweat. The results are read by taking a photo with a smartphone or attaching an electronic monitor.

When the team tested the sweat monitors on 12 volunteers on exercise bikes, sweat lactate levels didn't correspond well with blood lactate levels, but the acidity of sweat did (*Science Translational Medicine*, doi.org/ngd4).

However, this was only the case for sweat from skin near the working muscles, which in this case was monitored by the bands being around the ankles. Measurements by bands on the wrists of the cyclists didn't reflect blood lactate levels. ▮

Astronomy

The day a surprise asteroid hit Earth – harmlessly

Matthew Sparkes

ALLAN MADELAR/FACEBOOK

Asteroid 2024 RW1 was seen arriving over the Philippines

AN ASTEROID slammed into Earth's atmosphere and burned up near the Philippines on 5 September. It was spotted by astronomers only hours before it streaked across the sky in a bright fireball, but went unseen by many on the ground who found clouds blocking the view.

The asteroid, estimated to be roughly 1 metre across, was spotted by the NASA-funded Catalina Sky Survey and initially given the designation CAQTDL2, before being named 2024 RW1. As predicted, it struck at around 0046 local time, just east of the northernmost island of the Philippine archipelago. It is thought to have hit the atmosphere at a speed of 17.6 kilometres per second, or 63,360 kilometres per hour, which Alan Fitzsimmons at Queen's University Belfast in the UK says is about average for such objects.

"Don't be fooled by Hollywood movies where you can see the thing coming screaming through the sky and you've got time to run out the house, get the cat, jump in the car and drive somewhere. You don't have the time to do that," he says.

Fortunately, there was no need for an evacuation: NASA's Planetary Defense Coordination Office posted on social media that the asteroid had "safely impacted Earth's atmosphere".

"Survey telescopes are now good enough to spot these things coming in and give us a bit of warning"

"An object this small can't do any damage on the ground. We're protected from them by the Earth's atmosphere," says Fitzsimmons. A video shared on social media shot from the province of Cagayan at the northern tip of the Philippines shows a flickering green fireball appear behind the clouds, followed by an orange tail.

Fitzsimmons says that two or three objects this size strike Earth every year. We are increasingly able to spot them early, with the first incoming asteroid that was detected by astronomers before landing being in 2008. 2024 RW1 is the ninth accurately predicted asteroid strike on Earth. "The really positive aspect about this is that the survey telescopes are now good enough to spot these things coming in and give us a bit of warning," he says.

Larger space rocks are also of limited concern. "We believe we know more than 90 per cent of [near-Earth] asteroids that are about 1 kilometre in size, where 1 kilometre is considered not a planet killer, but something that would destroy a whole region or a whole continent," says Ian Carnelli at the European Space Agency (ESA).

Both NASA and ESA now have dedicated programmes for spotting and tracking asteroids, which involve a large network of dedicated observatories, existing and new, as well as amateur astronomers who take readings of the positions of known objects so that their orbits can be better predicted.

Carnelli is also part of efforts to hone asteroid defences. He is project manager of ESA's Hera mission, which is designed to study the aftermath of an earlier NASA mission that smashed into an asteroid to try to change its orbit. Hera will launch next month to verify the results of the impact up close, and further improve our understanding of planetary defence. "We have developed, and we are developing, real planetary defence systems," he says. ▮

Additional reporting by James Dinneen

Climate change

Jet stream shift is under way

Climate models have been predicting that global warming could send crucial wind patterns polewards and we are now seeing signs this has started, reports **James Dinneen**

SECTIONS of the planet's jet streams have begun shifting towards the poles over the past several decades. This is most likely a response to global warming, and could exacerbate heat and drought in regions that depend on the winds to steer storms their way.

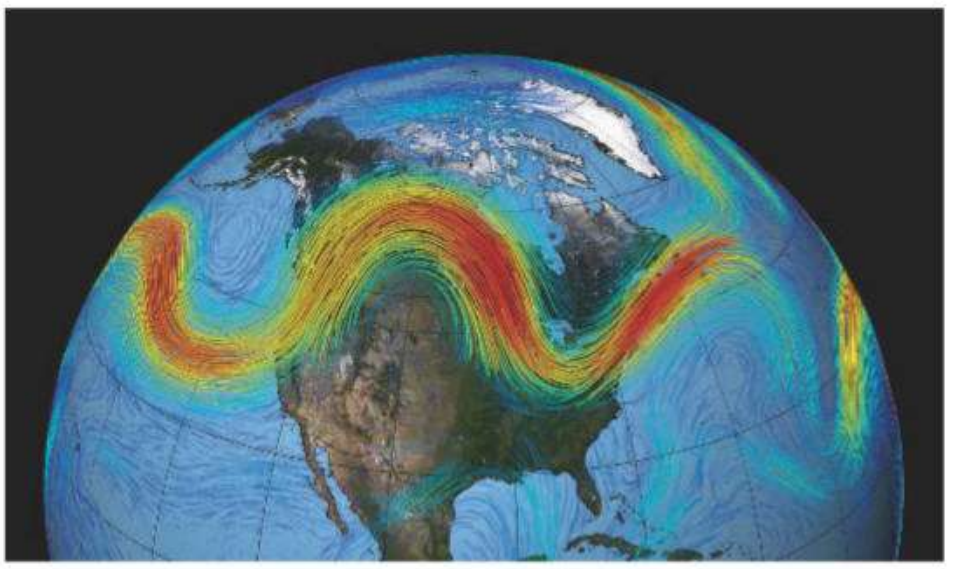
Jet streams are bands of rapid winds high in the atmosphere that blow from west to east around the mid-latitudes and the poles. This is sometimes referred to as "the jet stream", but separate ones exist in each hemisphere and at various latitudes and altitudes. They are driven by Earth's rotation and temperature differences between the tropics and higher latitudes.

Climate models have long anticipated that global warming would cause a poleward shift in the jet streams. This is expected to occur as increasing heat in the tropics pushes the storms that add fuel to the jet streams further from the equator. But the short satellite record of global winds has made it challenging to know if these wind patterns were changing with any clear trend. That record begins around 1980 and has only recently become long enough to begin reliably detecting a pattern, says Thomas Keel at University College London. "It looks like it's happening now – it has emerged from the noise," he says.

He and his colleagues analysed the jet stream above the North Pacific Ocean using datasets on wind speed in the region spanning 1980 to 2022. They found that its average position between December and February has seen a statistically significant shift northward of around 30 to 80 kilometres per decade (*Geophysical Research Letters*, doi.org/ngf4). However, the jet streams aren't changing in the same way everywhere, says Keel.

He says the short record means it remains unclear whether this movement is greater than past variability. But models project that this effect will continue in coming decades, expanding to other months by the end of the century under a high-emissions scenario.

Oscillations in the northern hemisphere's polar jet stream



NASA/GODDARD SPACE FLIGHT CENTER SCIENTIFIC VISUALIZATION STUDIO

In a 2023 study, Tim Woollings at the University of Oxford and his colleagues took a more general look at jet streams across both hemispheres. They found that, when analysed in combination, they show a clear poleward shift in their average position between 1979 and 2019. The trend has been clearest above the Southern Ocean, where the jet stream is also influenced by the ozone hole over Antarctica. "For the other cases it's really starting to emerge now," says Woollings.

Shifts in the position of the jet streams have an effect on global weather. For instance, a move in the North Pacific Jet Stream could exacerbate heat and drought in the western US by redirecting storms. Other regions that are influenced by jet streams, such as the Mediterranean, Chile, South Africa and Australia, could be affected by similar changes, says Woollings.

"If you're right on the edge of the region that gets rainfall due to the jet stream, even a degree shift of latitude could be really serious," he says. ▮

Microbiology

Bacteria can anticipate the changing seasons

DESPITE being among the simplest forms of life on Earth, cyanobacteria can predict and prepare for the changing seasons.

It has been known for more than a century that complex organisms can utilise day length as a cue for future environmental conditions – days get shorter before it gets colder, for example. Phenomena like migration, flowering and seasonal reproduction are all guided by such responses in plants and animals, known as photoperiodism, but it has never been seen in simple life forms such as bacteria until now.

Luísa Jabbur, then at Vanderbilt University in Nashville, Tennessee, and her colleagues exposed *Synechococcus elongatus* cyanobacteria to varying day lengths and found that those that experienced simulated short days went on to be two to three times better at surviving ice-cold temperatures, indicating they had prepared for winter-like conditions.

By testing shorter and longer periods, the researchers determined that it takes four to six days for the response to develop (*Science*, doi.org/ngd6).

These organisms spawn a new generation in hours, so the cells must pass on day-length information to their descendants.

Cyanobacteria, which capture energy from sunlight through photosynthesis, have existed for more than 2 billion years and are found almost everywhere on Earth.

"This is a phenomenon that evolved much earlier than we might have imagined"

"The fact that an organism as old and as simple as a cyanobacterium can have photoperiodic responses suggests that this is a phenomenon that evolved much earlier than we might have imagined," says Jabbur, who is now at the John Innes Centre in Norwich, UK.

Looking at how patterns of gene expression changed in response to day length, the team found that photoperiodism probably evolved by co-opting existing mechanisms to combat acute stresses such as bright light and extreme temperatures. ▮

James Woodford

Field notes Woodside Energy's Karda facility, Perth, Australia

Are humanoid robots the future of space exploration?

James Woodford pulls on a control headset and takes NASA's impressive Valkyrie robot for a spin to find out

I AM standing before one of the most advanced robots in the world and am awestruck by its humanoid form. Part Transformer, part *Star Wars* stormtrooper and with hands that look like they can crush beer cans, at 1.8 metres tall and weighing 120 kilograms, NASA's Valkyrie robot is an intimidating figure.

But it is the face that most transfixes me. Where the eyes, mouth and nose should be is a cavity filled with whirring and flashing sensors, including lidar detectors that give the robot both a three-dimensional view of the world and an impenetrable, no-nonsense expression.

That is apt, because while current fashionable advances in AI, like ChatGPT, aim to automate office work and creativity, the people behind Valkyrie are more focused on jobs that are too dangerous for humans – both on Earth and, one day, in space.

NASA has five Valkyrie robots around the world, but the one I am visiting today is at the Karda facility in Perth, Western Australia, a lab owned by Woodside Energy, an oil and gas company. With its large-scale offshore infrastructure, the global energy giant makes a good partner for exploring how humanoid robots could be sent into inhospitable environments to complete dangerous tasks.

Valkyrie's two arms and legs and complex manipulation are particularly impressive, says Woodside's Gabrielle Pennock, who, like the rest of the team, shortens the robot's name to Val and calls it "she".

"That is unique with Val," says Pennock, "And I think she's probably the most complex – the digital integration of her systems, the sensor technology, that level of complexity. I don't think we really see that in any of our other robotic platforms."

AP PHOTO/ELISE AMENDOLA/ALAMY

Above: NASA's humanoid robot, ready to be inhabited via virtual reality; below: James Woodford takes a selfie with Valkyrie

Valkyrie is being put through its paces at the Karda facility so researchers can work out what it would take to get a humanoid robot onto offshore facilities or into space.

At first, I just watch as it is controlled via virtual reality, walking, spinning and bending steadily. Even so, I note the straps dangling from an overhead gantry. At a conservative cost of over $2 million, NASA doesn't want Valkyrie falling over.

"It's possible you could have an artificial human, like Data from *Star Trek*, but it's a long way off"

JAMES WOODFORD

Then, it is my turn. One of the team calls me over and fits me with a VR headset. I open my eyes and the room before me has been transformed into a digital rendering of the lab. In front of me, I can see a digital Valkyrie. On the floor, there is a digital hexagon and I am instructed to walk towards it. As soon as I am on the hexagon, my body looks and feels like it has merged into the robot's. Its arms become my arms and all of me is subsumed within it. In each of my hands I am holding a controller from which, in the digital-scape, two laser-like beams emerge pointing to the ceiling.

I am instructed to say the command to release Valkyrie into my control. But, with its name origins in Norse mythology, I misunderstand when Woodside robotics engineer Andrew Sherry instructs me to say "Thor everything". I am baffled until he realises my confusion. "T-H-A-W, thaw everything," he says, again.

Uttering the words, it is as if I can feel the robot wake up – a sensation the researchers describe as "riding the skin". I tentatively begin to move my limbs and can see the movement reflected in the virtual reality environment. Sherry confirms that the robot, standing a few metres in front of me, is following suit in the physical world. I move my head, crouch or bend and so does Valkyrie.

After a few minutes, I begin to feel more confident and dip my head in a full bow but, in my exuberance, I have bent too far for the gantry straps and Sherry tells me to straighten up. He asks me to say "freeze everything". As soon as I repeat the command I can sense the decoupling of Valkyrie from me and I step backwards, feeling myself emerge from its body. With that, the session is over and the robot is moved by trolley to a secure storage room.

So, have I just had a preview of what it will be like to explore space in a robot body? Not exactly, says Shaun Azimi at NASA's Johnson Space Center in Houston, Texas. He says none of the five Valkyries will ever go to space, but future robots that incorporate their technology will. In fact, while my time controlling Valkyrie felt high-tech, these versions are now over a decade old and may soon be retired, says Azimi.

Getting legless

One issue is that Valkyrie was built to walk in the gravity of Earth, but a zero-gravity version probably wouldn't need legs. Instead, the focus of the next generation will be on safety and reliability because the margin for error in space or harsh environments on Earth is small. Those who deploy humanoid robots need to be certain, for example, that they won't need a gantry to stop the robots falling over.

"The physical capability of Valkyrie is really strong, but where everybody's trying to catch up right now, including current industry, where the billions of dollars are

pouring in, is the intelligence and the adaptability, the resilience, the safety and predictability right to where we can have a robot that can always take the correct action," says Azimi.

While NASA built Valkyrie in-house, he says its successor will probably be the result of a challenge set by NASA for others. Then universities and commercial companies will innovate.

For example, he says, knowledge gained from the Valkyrie programme combined with advances from other research teams around the world will be directed to solving problems like gathering material from the surface of the moon's south pole.

As my time with Valkyrie begins to wrap up, I have a sense that I have witnessed a technology that is the beginning of a future that hasn't quite arrived. My mind is racing at the potential for a science fiction future of humanoid robots. Imagine combining large language models like ChatGPT with Valkyrie's manual dexterity, along with recent advances such as a robot overlaid with living human skin. Can a human-like robot be that far away?

"I think it's possible that you could have an artificial human, something like Commander Data from *Star Trek*, but I think it's a long way off," says Azimi. He says it is easier to envisage something like Hal from *2001: A Space Odyssey*, a computer voice embedded into a spaceship's systems, than a fully realised android.

In the meantime, Valkyrie and her successors have important work to do in Australia grappling with a space-like environment, says Azimi. "You can see sort of natural parallels to a future lunar or Mars base and that gives us the kind of proving ground in a realistic environment," he says. ▮

Infectious diseases

Experimental mRNA vaccine could help fight mpox

Carissa Wong

AN mRNA vaccine for mpox developed by biotech company Moderna has shown promise in monkeys, raising hopes that it could help to tackle the ongoing outbreak in West and Central Africa. Other vaccines for the virus exist, but a new vaccine based on mRNA technology would have advantages.

Nigeria, which has had 35 confirmed cases of mpox so far this year, has become the first country in Africa to gain mpox vaccines, with the arrival of 10,000 doses of the JYNNEOS vaccine. This shot contains a weakened form of the related vaccinia virus and helped high-income countries, such as the UK and US, curb cases during a global mpox outbreak in 2022.

mRNA vaccines, which began being used widely during the covid-19 pandemic, contain instructions for cells to produce viral proteins, so the immune system can learn to recognise them. Unlike other types of vaccine, they can be developed and manufactured quickly once the genome of a virus has been sequenced.

Galit Alter at Moderna in Massachusetts and her colleagues created a vaccine containing RNA sequences encoding proteins present in a family of viruses that includes mpox. They gave six macaques the mRNA vaccine and six a so-called MVA vaccine similar to JYNNEOS, while six macaques were unvaccinated. All the vaccinated animals survived a usually lethal dose of the virus, while five out of six unvaccinated animals died.

On average, animals that received the mRNA vaccine also had far fewer skin lesions than those that received the MVA vaccine or were unvaccinated (*Cell*, doi.org/nf8n).

The results stand a good chance of being replicated in humans, says Paul Ananth Tambyah at the National University of Singapore. A human trial has begun, with results expected next year.

Although the mRNA approach shows promise, the JYNNEOS vaccine works well against cases caused by the clade II variant that circulated in 2022. The current outbreak involves a different variant – clade Ib – but it is close enough to the earlier variant that the JYNNEOS vaccine should still work, says Jean Claude Udahemuka at the University of Rwanda.

"Countries in the West have vaccines in stock, and they should provide these to African countries"

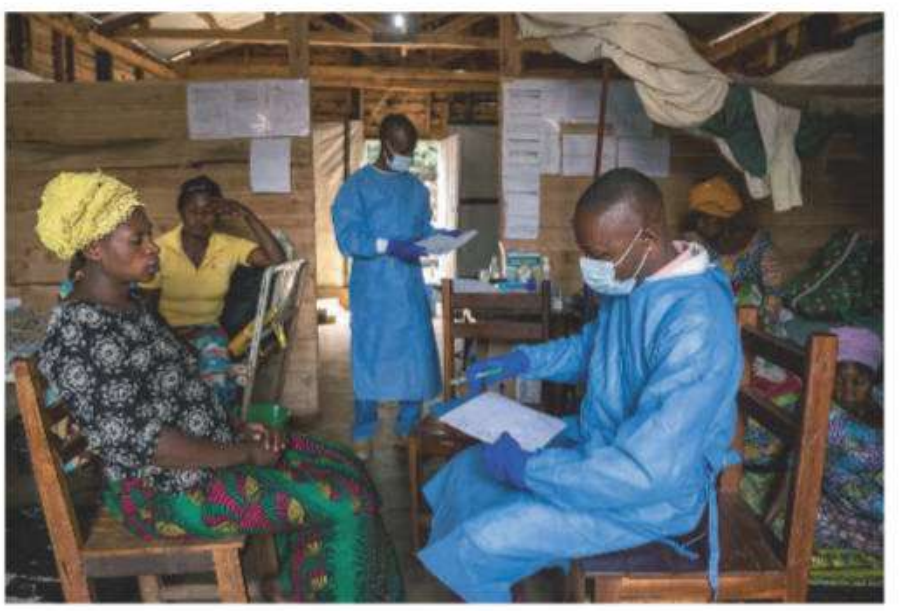
So are mRNA vaccines needed? Some researchers fear that the mpox virus, formerly known as monkeypox, could mutate, rendering existing vaccines less effective. In that case, mRNA vaccines will be needed, says Ranjit Sah at St. Elizabeth's Medical Centre in Boston.

Investing in mRNA vaccines against mpox would also help to boost vaccine supplies fast, says Ananth Tambyah.

However, mRNA vaccines must be kept frozen, making it hard for them to be used where cold storage and distribution infrastructure is limited. This means they are likely to benefit high-income countries rather than the countries worst affected, which will have to rely on access to existing vaccines.

"Some countries in the West have vaccines in stock, and they should provide these to African countries and other countries that are at risk, because people have to look at this as one boat that we are all in, and if it sinks, everyone will sink," says Udahemuka. ▮

An mpox treatment discussion in Kavumu hospital in the DRC



ARLETTE BASHIZI/BLOOMBERG VIA GETTY IMAGES

New Scientist Live

Where are you really from?
Hear Adam Rutherford on how science is a weapon against racism **newscientist.com/nslmag**

Neuroscience

Brain network linked to depression

A network of neurons in the brain seems to be larger in people with depression, which could change how we think about the condition's causes, says **Carissa Wong**

DEPRESSION has been linked to a larger-than-expected network of neurons that work together across the brain, but not everyone is convinced that it actually causes the condition.

Like many medical conditions, depression doesn't have a single cause, but can be brought on by a traumatic life event, such as a bereavement, and has also been linked to genetics.

Studies also suggest that depression is tied to certain parts of the brain being smaller – such as the hippocampus, which is involved in memory, and the thalamus, which processes sensory information – than in people without the condition. But a review of 14 studies concluded that there was no robust relationship between smaller brain structures and depression.

Now, Charles Lynch at Weill Cornell Medicine in New York

"These results will make all of us scratch our heads and say, 'what does this mean?'"

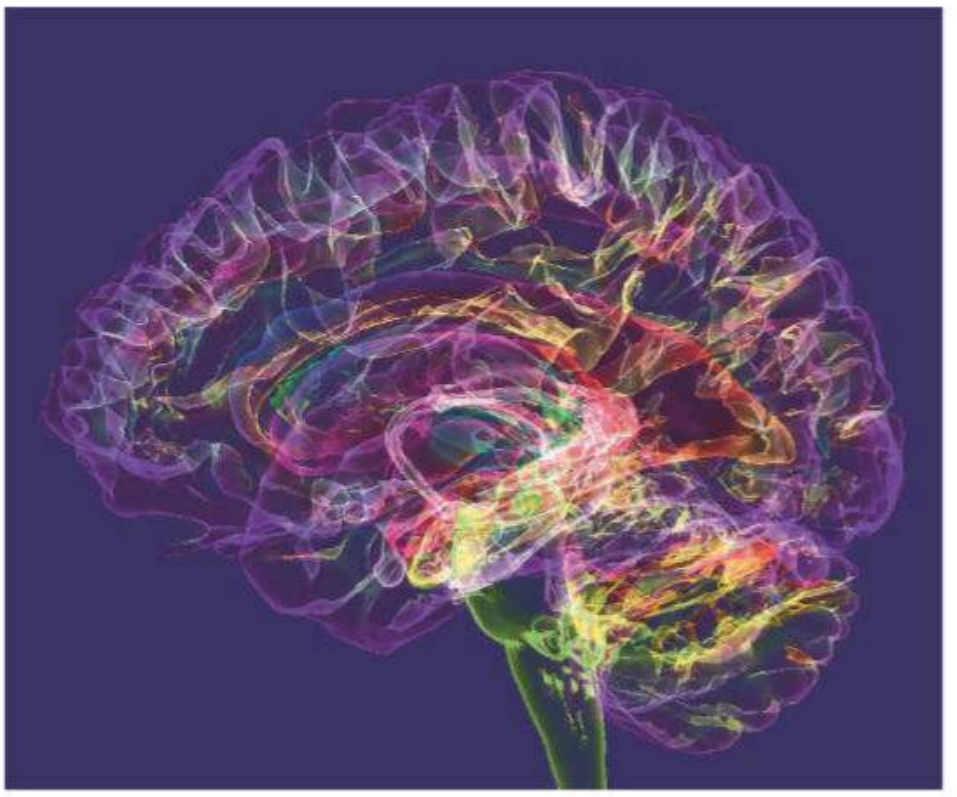
and his colleagues have found that the condition may also involve a network of neurons across the brain that become activated together (*Nature*, doi.org/nf78).

The researchers scanned the brains of six people who had been diagnosed with mild to severe depression for more than 10 hours across about 20 sessions. They found that the so-called salience network was twice as large in four of them as it was in 37 people with no depression diagnosis, who were also scanned. Located in the cerebral cortex, the brain's outermost layer, this network has been linked to attention and the ability to respond to stimuli.

Lynch and his team found similar results in three other groups, each made up of more than 40 adults, with and without depression. Finding the same results again has persuaded some other scientists that the link between a large salience network and depression is genuine. "It's quite convincing," says Thomas Yeo at the National University of Singapore. "I think this is one of the best studies."

The researchers themselves acknowledge that not everyone with depression will have such an enlarged salience network, as demonstrated by two of the initial participants having a network that was similar to that of the controls. They aren't currently able to explain this, says Lynch. The team didn't find that depression severity, for example, was linked to a particularly large network.

For Daniela Espinoza Oyarce at the Australian National University in Canberra, a pertinent question isn't just whether there is a link between variations in brain structure and depression, but also, among people with these traits, which came first. To get to the bottom of this, Lynch and his colleagues also analysed data from a previous study, made up of children who didn't show signs of depressive symptoms when aged 10 or 12, but who went on to develop these symptoms in the next couple of years.



K H FUNG/SCIENCE PHOTO LIBRARY

Many different regions across the brain may be involved in depression

36%

A network of neurons covered this much more of the brain's cortex in children who went on to develop depression

They found that even before these children developed these symptoms, they had a salience network that spread across 36 per cent more of their cerebral cortex than that of children who hadn't developed depression symptoms by the same age. "This suggests to us that salience network expansion possibly predisposes somebody to depression, rather than being a consequence of depression," the researchers write.

"I think their evidence is really pretty strong that this is a pre-existing change that influences the risk of depression," says Yvette Sheline at the University of Pennsylvania.

But Espinoza Oyarce wants more research on larger groups of people before she is convinced. Another factor, such as stress, could also be involved, says Yeo. "Social factors might cause both an increase in the network size and depression," he says.

Getting to the bottom of this is important, because the size of someone's salience network may one day help to predict their risk of depression, says Yeo. But Espinoza Oyarce and Ian Hickie at the University of Sydney in Australia both say that measuring the network size is unlikely to ever be used to diagnose depression, given the cost and other impracticalities of brain scans.

However, Hickie says research on the salience network could one day show that the size of the network in someone with depression affects how they will respond to treatment.

"I was certainly not expecting these results, and so it will, I think, make all of us scratch our heads and say, 'what does this mean? Where do we go from here?'," says Sheline. ▮

See page 32 for more on the brain and mental health

New Scientist Live

The social brain

See three experts explore the psychology of group dynamics newscientist.com/nslmag

Environment

Bat die-off led to more insecticide use and rise in infant deaths in US

Michael Le Page

THE decline of bats in the US due to the spread of a fungal disease slashed farmers' earnings and led to an additional 1300 deaths in children under 1 year old, although the exact link is unclear.

In counties where the bat disease is present, farmers increased their use of insecticides by 31 per cent to make up for the reduction in insect predation by bats, Eyal Frank at the University of Chicago has found. Between 2006 and 2017, farmers in affected counties lost $27 billion as a result of lower crop sales and higher insecticide costs, he calculates.

What's more, in the affected counties, there was also an 8 per cent rise in the number of children dying before 1 year of age, which Frank attributes to the increase in insecticide use.

"Insecticides are toxic by design," he says. "Even when they are used at regulatory levels, there seems to be a health cost."

In 2006, hibernating bats with a white fungus on their muzzles were seen in a cave in New York state, with many dying. White-nose syndrome, as it is known, has been spreading across North America ever since, killing millions of bats.

Frank has used data from agricultural censuses to compare counties where white-nose syndrome has been detected with those where it wasn't yet present up to 2017 – stopping that year because the census data is only released every few years.

In affected counties, insecticide use rose every year after the detection of the disease, but remained broadly constant in other areas.

He then looked at data on infant mortality, excluding deaths due to accidents and murders. The 8 per cent rise in affected counties would have resulted in an extra 1300 infant deaths by 2017, he calculates (*Science,* doi.org/ngcm).

Frank thinks his findings go beyond correlation to show that the die-off of bats is the cause of both higher insecticide use and higher infant mortality. He says the compelling thing is that the trajectory of counties changed in the same way once the disease reached them, whatever year the disease arrived.

"Insecticides are toxic. Even when they are used at regulatory levels, there seems to be a health cost"

How higher insecticide use led to higher infant mortality isn't clear. "I can't say anything about the direct exposure mechanism, only that my results are not consistent with the idea of exposure through food," says Frank. That leaves breathing in insecticides or contaminated water supplies as the most likely routes.

"Frank convincingly demonstrates that in counties affected by white-nose syndrome, insecticide use increases compared to counties that are not affected," says Roel Vermeulen at Utrecht University in the Netherlands.

However, Vermeulen says that the loss of income would lead to more stress in farming communities, and that this could also contribute to infant mortality. "Therefore, it is questionable whether the observed effects on infant mortality can be solely attributed to increased insecticide use," he says. ▮

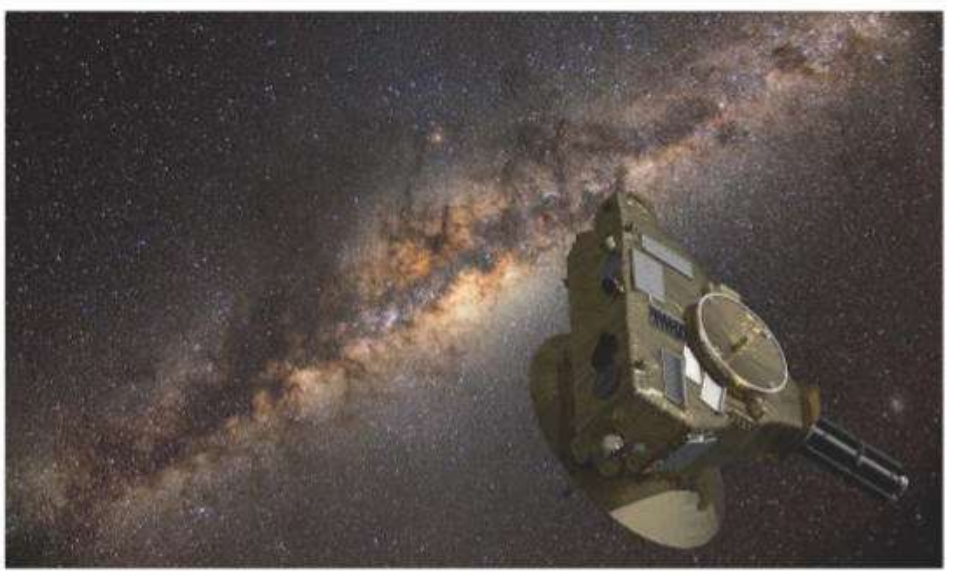
Astrophysics

We finally know exactly how dark it is in deep space

NASA's New Horizons spacecraft has made the first precise measurements of the ambient light that suffuses the universe, called the cosmic optical background.

This glow is so dim that it is impossible to measure with precision from Earth – the light from objects in the inner solar system far outshines it. "It's like trying to see the faint stars in the Milky Way from Broadway in NYC," says Marc Postman at the Space Telescope Science Institute in Maryland.

But New Horizons has travelled far enough to avoid some of that light pollution. After visiting Pluto in 2015, the spacecraft continued moving away from us – it is now about 8.7 billion kilometres from Earth. That is still within our solar system, but far from its bright lights.



NASA, APL, SWRI, SERGE BRUNIER (ESO), MARC POSTMAN (STSCI), D. DURDA

NASA's New Horizons spacecraft has been looking into dark regions of space

With its camera shadowed by the body of the spacecraft, pointed away from the sun and the disc of the Milky Way, New Horizons took 24 images of dark areas of space.

Postman and his colleagues then calculated how much of the light in those images originated from stars and dust within our galaxy, and subtracted that to find the total amount of background light. The result was an astonishingly dim glow of roughly 11 nanowatts per square metre per steradian, or sector, of the sky (*The Astrophysical Journal*, doi.org/nf3z).

It is as if you were in a deserted cabin on a moonless night, more than a kilometre from your nearest neighbour, and that neighbour's refrigerator door light was on, says Postman. "It's 100 times darker than even the darkest sky you can see from Earth."

While it may be faint, this background is composed of all of the light from all of the galaxies that we can see in the cosmos. Earlier measurements hinted that there could be some unexplained extra light there, but these new observations dispel that idea. ▮

Leah Crane

Archaeology

Greenland's mysterious early culture

On a recent expedition, researchers braved summer storms in northern Greenland to learn the secrets of the ancient peoples who lived there 4500 years ago, reports **Becky Ferreira**

SOME 4500 years ago, as the Great Pyramid of Giza was being erected and the Indus Valley civilisation hit its peak, a group of Arctic peoples migrated to a region of northern Greenland now known as Inutoqqat Nunaat, or the "land of the ancient people".

They were the northernmost culture on Earth at the time, living just 800 kilometres from the North Pole, but little has been known about their diet, customs or survival strategies in this extreme climate. Now, that is starting to change.

On 30 July, researchers with the Wandel Dal Project set off on an expedition to understand this ancient civilisation. "It's a mystery," says Bianca Perren at the British Antarctic Survey, who was part of the expedition. "So little is known about them."

These peoples lived in lakeside tents fixed in place by stone rings that remain eerily untouched to this day. Previous expeditions have found small tools, including microblades, suggesting that they hunted musk ox on land and char in the lakes, while hearths and mid-passages – stone structures that run through the centre of the rings – provide a glimpse of how they kept warm during sunless winters that lasted six months.

Miniature tent rings at some sites might be the remains of children's toys, similar to dollhouses, opening a window into the domestic lives of these peoples. "These dollhouses are all matching colours with matching stones in the centre," says Perren. "You can imagine families here. To have 4000-year-old dollhouses, sitting on this landscape, is just insane."

On this year's expedition, the team extracted sediment cores to learn about the past climate and survey archaeological features.

The people who migrated out of the Canadian Arctic 4500 years ago split into two groups: one that went across northern Greenland, called the Independence I culture, and another that went down the west coast of Greenland, called the Saqqaq people. The Wandel Dal Project is focused on the Independence I group, named after Independence Fjord, a formation near their settlements.

Unlike later cultures that lived in Greenland, including the Thule, ancestors of the Inuit peoples, the Independence I culture didn't travel with dog sleds and would have roamed the vast wilderness on foot. Their inland migration may have been buoyed by a period of warmer and wetter weather, says Jens Fog Jensen at the National Museum of Denmark, who isn't involved with the Wandel Dal Project. "Wandel Dal might have been greener at the time of the arrival of Independence I," he says. "In 2500 BC, there was more open water and probably large stocks of musk ox that had never been hunted by humans."

FUUJA LARSEN

Above: a microblade stone tool found in Greenland. Below: Researchers survey archaeological features in Wandel Dal valley, Greenland

"You can imagine families here. To have 4000-year-old dollhouses sitting on this landscape is insane"

FUUJA LARSEN

But about 700 years after these peoples first appeared, they mysteriously vanished.

A second culture, known as Independence II, emerged about 1000 years after the first, but it also disappeared, in about 100 BC. Untangling the history of the broader region, called Peary Land, has been complicated by the near-total absence of human remains.

Those working on the Wandel Dal Project, which includes many Greenlanders, were also at the mercy of the High Arctic's unpredictable weather. The team relied on Twin Otter planes and helicopters to reach the field site, but storms limited the latest expedition to just four days instead of two weeks.

With the sediment cores, the researchers hope to reconstruct the climatic and environmental shifts that may have shaped the lives of the region's ancient peoples.

"The High Arctic environment, with its cycles of light and darkness, cold and ice, was not just a backdrop for survival, but a landscape full of resources that the Independence I people skilfully exploited," says Mari Kleist at the University of Greenland. "Their ability to hunt, as well as to store and preserve food, indicates a deep understanding of the environment and its cycles."

Perren and her colleagues felt a connection to the Independence I people, despite being separated from them by thousands of years. "There's something about being in these sites where you're camped and where these ancient people lived, looking at the same views and trying to understand how they lived, what the environment was like and how it changed," Perren says. "It's pretty magical." ▮

New Scientist Live

Death and disease in the Middle Ages

Hear Alice Roberts reveal new details about old diseases **newscientist.com/nslmag**

Space

Did collision with a huge asteroid knock Ganymede askew?

Jacklin Kwan

A MASSIVE impact billions of years ago may have reoriented Jupiter's largest moon.

Naoyuki Hirata at Kobe University, Japan, and his colleagues have studied Ganymede's extensive furrow system – a series of concentric troughs believed to be remnants of the largest impact structure in the outer solar system.

The centre of the furrow system aligns with Ganymede's tidal axis, the imaginary line running to Jupiter from the centre of the moon's side that always faces the planet. This led the researchers to suggest that the impact that formed the furrows caused a redistribution of mass that reoriented the moon.

Through simulations, Hirata and his colleagues determined that the impactor responsible probably had a diameter of about 150 kilometres. That is much larger than the one that caused the extinction of the dinosaurs on Earth, thought to have been about 10 kilometres across.

Andrew Dombard at the University of Illinois Chicago says that if an asteroid like that hit Earth, "it would be a global sterilising event, a bad day".

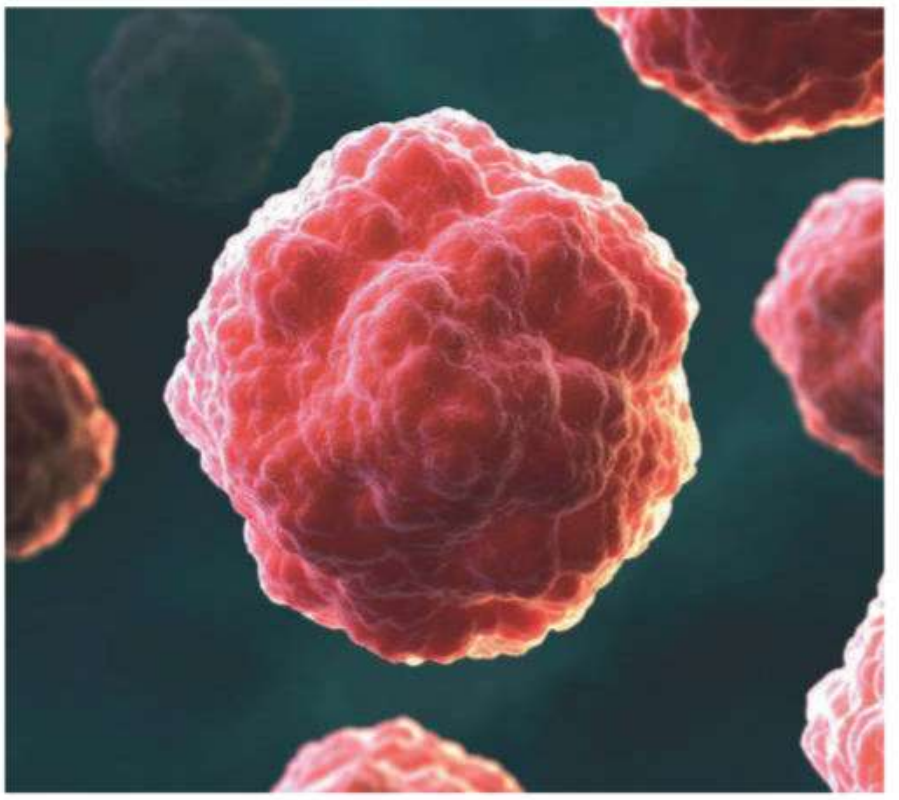
Upon impact, this asteroid would have breached Ganymede's icy crust and penetrated into the liquid oceans below, creating a transient crater and hurling vast amounts of material across the moon's surface. As this settled, it would have formed a blanket of ejecta around the impact site, creating a region where gravity is stronger due to the extra mass. Over time, this would have made Ganymede reorient, aligning the impact site with its tidal axis (*Scientific Reports*, doi.org/nf34).

However, although it is likely that the impact affected Ganymede's early history, estimating the size of the object that hit is complicated because we lack good data on the gravity and topography of this frigid world, says Hirata. ▮

Health

Lab-grown stem cells could be a breakthrough for cancer therapy

James Woodford



ANIMATED HEALTHCARE LTD/SCIENCE PHOTO LIBRARY

Stem cells can produce other types of cell when they divide

HUMAN blood stem cells have been made in a laboratory for the first time, which could significantly improve how we treat certain types of cancer.

Treating cancers such as leukaemia and lymphoma via radiation and chemotherapy can destroy the blood-forming cells in bone marrow. A stem cell transplant means that new, healthy bone marrow and blood cells can grow. Umbilical cords are a particularly rich source of stem cells, but donations of these are limited and the cells can be rejected by the recipient's body.

The lab-grown cells have so far been tested only in mice, but when infused into the animals, the cells became functional bone marrow at similar levels to those seen after umbilical cord blood cell transplants.

The new method would allow researchers to produce stem cells from the actual patient, eliminating the supply issue and reducing the risk that their body would reject them.

First, Andrew Elefanty at the Murdoch Children's Research Institute in Melbourne and his colleagues turned human blood or skin cells from several donors into so-called pluripotent stem cells through a process called reprogramming.

"This involves temporarily turning on four genes, with the result that the patient cells revert to an early stage of development when they can become any cell in the body," says Elefanty.

"The approach could be scaled up to produce a never-ending supply of blood stem cells"

The second stage consisted of turning the pluripotent cells into blood stem cells.

"We first make thousands of small floating balls of cells, a few hundred cells in each ball, and direct them to change from being stem cells to sequentially become blood vessels and then blood cells," says Elefanty.

This process, called differentiation, takes about two weeks and makes millions of blood cells, he says.

Elefanty and his colleagues then infused these blood cells into mice that lacked an immune system and the cells became functional bone marrow in up to 50 per cent of cases (*Nature Biotechnology*, doi.org/nf33). This means the blood marrow made the same cells that carry oxygen and fight infections as healthy human bone marrow does, says Elefanty. "It is this unique ability to make all the blood cell types for a prolonged period of time that defines the cells as blood stem cells," he says.

Abbas Shafiee at the University of Queensland in Brisbane says the work is a "magnificent breakthrough" towards new therapies for blood cancers. "It has not been done before and it has a lot of potential for the future." But even once animal testing is complete, a lot of research in humans needs to be done before the approach can be used in clinics, he says.

Simon Conn at Flinders University in Adelaide, Australia, says a key advantage of the team's approach is that it could be scaled up to produce "an essentially never-ending supply" of blood stem cells.

But he adds that the rate of success and the diversity of the blood cells varied depending on the donor. "This suggests the treatment, even at the preclinical stage in mice, is not consistent, which will need to be addressed prior to any clinical trials in human patients," says Conn. ▮

Technology

Google takes a quantum leap

A breakthrough from Google means quantum computers could now make fewer errors as they get bigger. This could pave the way for the machines to solve useful real-world problems, says **Matthew Sparkes**

IF A small quantum computer makes a small number of errors, will a large quantum computer make even more, rendering it completely useless? No, say researchers at Google, who have made a key breakthrough in error correction for quantum devices, setting out a path to creating machines that are useful and practical.

Ordinary computers store data as bits that are either a 0 or 1, but errors can cause these to "flip" to the wrong value, which is why devices ranging from smartphones to supercomputers have built-in error correction. Quantum computers are even more prone to errors, but the problem is also more complex for them because each quantum bit, or qubit, exists in a mixed state of 0 and 1, and any attempt to directly check its value destroys the fragile quantum state.

To solve this, quantum computers can be made to group a number of physical qubits to act as a single "logical" qubit, allowing for cross-checking of values while preserving their quantum state. In this scenario, instead of directly checking the value of a qubit, a technique called surface code correction lets you observe the relative properties of the physical qubits in different ways, which can give hints that an error has occurred.

But this introduces a further problem, as Google discovered in 2021, because adding more physical qubits unhelpfully introduced even more errors than they solved. The goal was to find a way of reducing errors faster than they were introduced, a breakeven point known as the threshold.

Google now says it has crossed that threshold. In experiments, researchers at the company were able to pass the breakeven point with a 72-qubit processor and a 105-qubit processor, each acting as a single logical qubit. In one test, the logical qubit preserved quantum information for more than twice as long as any of the physical qubits it was made up of could do individually. In their paper on the work, the researchers claimed an error rate of just 0.143 per cent per cycle of the machine – better than previous quantum machines but still high enough to cause problems with large calculations (arXiv, doi.org/nf8j).

Google declined to speak to *New Scientist*, but in the paper the researchers say that although previous efforts by other teams had "demonstrated different features of quantum error correction", they fell short of a definitive display, which the firm now claims to have made. "With below-threshold surface codes, we have demonstrated processor performance that can scale in principle, but which we must now scale in practice," writes the team.

But the researchers also warn that significant hurdles remain. Improving their processors to the point of only making one error per million operations would be "resource intensive in practice" and require 1457 physical qubits for each logical qubit – which is more than what is contained in even the largest quantum computers currently in existence.

0.143%
the error rate for each cycle of Google's quantum machine

105
physical qubits acted together as a single logical qubit

1457
physical qubits are needed to cut errors to one in a million operations

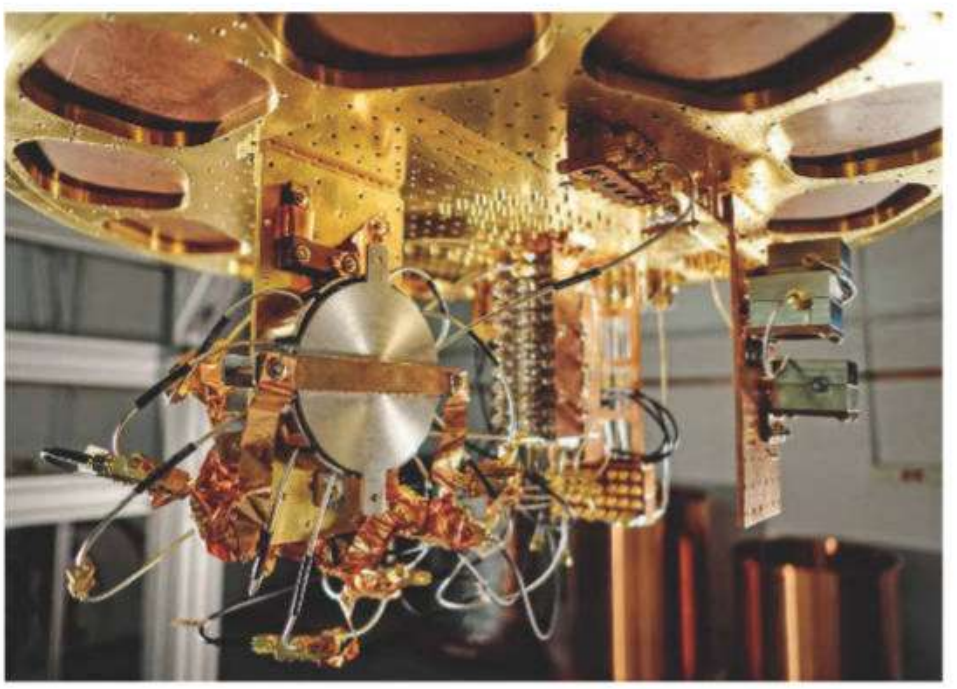
Google is now in a race to scale up its quantum computers as rivals attempt to do the same. One key question is whether Google's chosen architecture, using superconducting qubits, will prove to be the correct way forwards. Teams using an alternative approach based on trapped ions have previously demonstrated error correction, but only for a dozen or so physical qubits.

Scott Aaronson at the University of Texas at Austin says the work pushes quantum computing nearer to practicality and is a vindication for Google's choice of quantum technology over that of its competitors. "I'd characterise this as another significant step forward in realising error correction, and as representing a collective effort of Google's experimental group for the past couple years," he says. "Trapped ions and neutral atoms pushed ahead of superconducting qubits lately in terms of fidelity, so the ball has really been in the court of Google, IBM and the other superconducting groups to answer that challenge, and this could also be seen in that light."

Martin Weides at the University of Glasgow, UK, says the current generation of quantum computers can do nothing useful that couldn't be done with the computer power found in a smartphone, but that Google's latest work demonstrates the machines can at least be scaled up in a practical way in the future.

"They really showed that by putting qubits together, you reduce the error rate. You actually get better and better," he says. It probably isn't useful yet, and you would need tens of thousands or millions of error-corrected qubits to build anything useful, he says. "But it's a great demonstration of the concept." ▮

Quantum computers, like this one from Google, are limited by their error rate



ERIK LUCERO/GOOGLE

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Health

Most detailed map of uterine lining yields clues about endometriosis

Grace Wade

THE endometrium, or the inner lining of the uterus, has been mapped in unprecedented detail. The information gleaned will improve our understanding of reproductive health and common conditions such as endometriosis.

The endometrium is one of the most dynamic organs in the body. Each menstrual cycle, it thickens in preparation for pregnancy and, if a pregnancy doesn't occur, sheds its top layer during menstruation.

Despite the endometrium's pivotal role in reproductive health, we know little about this tissue. "It is kind of a black box," says Roser Vento-Tormo at the Wellcome Sanger Institute in the UK.

Now, Vento-Tormo and her colleagues have analysed more than 313,000 endometrial cells from 63 people of reproductive age. Samples were collected throughout the menstrual cycle.

Using a technique called single-cell sequencing, the researchers measured which genes were turned on or off in each cell. This allowed them to identify each type of cell and gain new insights into their functions. They then analysed endometrium tissue samples under a microscope to determine the location and structures of cells, creating a map.

CONNECT IMAGES/ALAMY

The endometrium, or uterus lining, changes dramatically during the menstrual cycle

The researchers found that the composition of the organ changes every four or so days, says Vento-Tormo. "It was a bit unexpected, even for us, how dynamic it was."

"Despite the endometrium's pivotal role in reproductive health, we know little about this tissue"

She and her colleagues also discovered new cell types, such as one in the endometrium's lower layer that changes across different stages of the menstrual cycle (*Nature Genetics*, doi.org/gt79tm). This type of cell, which can morph into other types of cells, may help regenerate the upper layer of the endometrium after menstruation.

Impairments in these cells might contribute to heavy menstrual bleeding or other conditions where the endometrium doesn't properly develop, says Christine Metz at the Feinstein Institutes for Medical Research in New York.

The atlas also yielded clues about endometriosis, a painful condition in which tissues similar to those lining the uterus grow outside it. Samples from people with endometriosis showed impaired communication between the endometrium's structural cells and those that respond to hormonal changes. The insight could lead to new treatments.

The map may improve our understanding of causes of infertility, too, such as why some embryos can't implant in the uterus lining, says Vento-Tormo.

"I think this map is going to contribute immensely in the coming years to understanding conditions that affect the endometrium," says Metz. ▮

Zoology

Wild bees find a home in the sandy sidewalks of Berlin

PAVEMENTS can be unlikely havens for wild bees and other insects, a survey of streets in Berlin hints.

Sophie Lokatis at the Free University of Berlin and her colleagues explored 200-metre-long sections of pavement at 12 locations in the German city.

They recorded insect nest locations and collected individuals found at the entrance to nests, crawling on the sidewalk or flying within a metre of the ground. They also analysed soil from nests using DNA sequencing techniques.

The team recorded 66 species using pavements as a habitat. Many of these were pollinators and other beneficial insects, including 28 species of wild bees and 22 species of solitary and parasitoid wasps.

They also found that there were more nests, and a higher diversity of species, on pavements within 200 metres of insect-friendly flower gardens, created by local initiatives (*Urban Ecosystems*, doi.org/nf32).

"Only a few years ago, insect-friendly gardens near apartments and extensive, rarely cut meadows in parks were almost unthinkable," says Lokatis. "This has shifted dramatically."

Berlin's pavements mainly consist of small cobblestones or blocks with a sand mixture between them, where insects can dig burrows. The benefits of this kind of paving can be an example to other cities, especially considering the negative effects asphalt has on urban biodiversity, says Lokatis.

The findings disprove the idea that cities are biodiversity deserts, says Sarah Parsons at Western Carolina University in North Carolina. "The effect of urbanisation on species can be quite complex and can, in some cases, result in a greater diversity of species than we may expect," she says. "The study underlines the importance of flower gardens in urban spaces to promote bee and wasp diversity, and paves a path forward for how we can design future cities." ▮

Gary Hartley

A *Sphecodes* cuckoo bee, or blood bee, on the streets of Berlin

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Comment

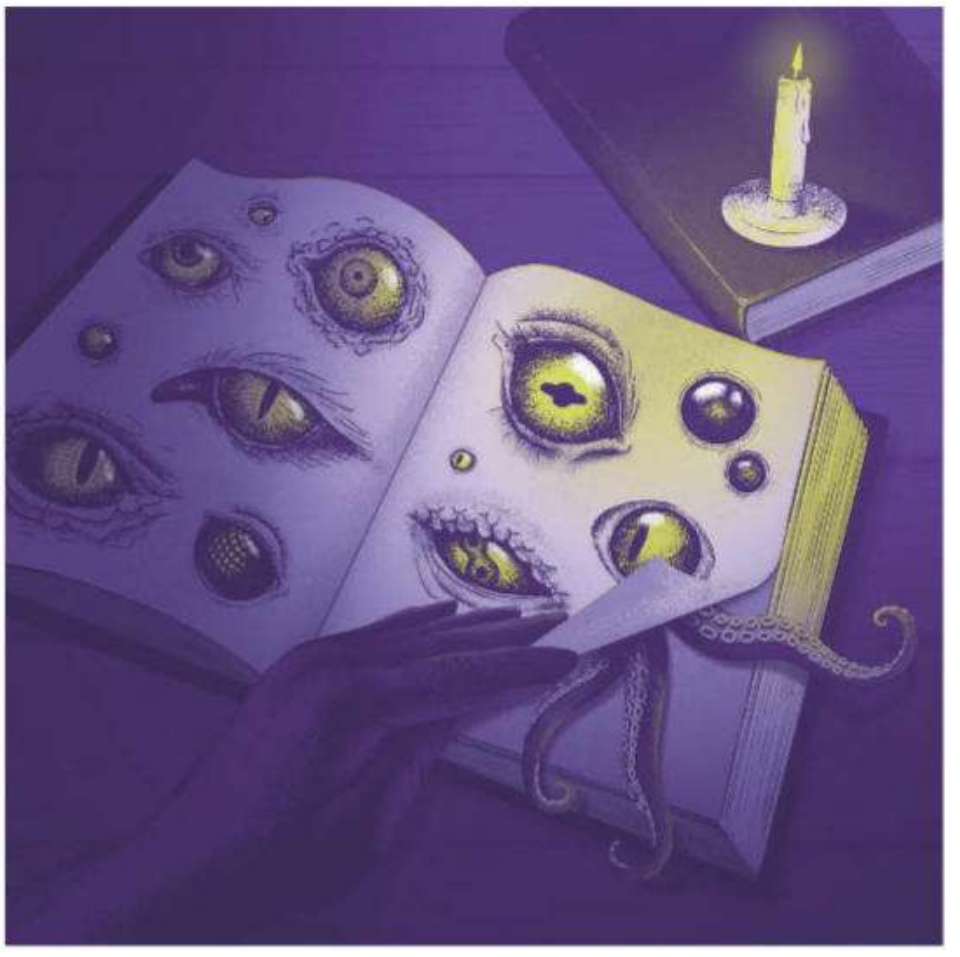
Something wicked...

From serpents to zombie pathogens, there is science behind our love of monsters – and it tells us a lot about ourselves, says **Natalie Lawrence**

AS FRIGHTENING as monsters are, they have always captivated us. From chimeras and hydras to bunyips and golems, creatures have emerged from our imaginations throughout history and across cultures. Today, they explode onto our cinema screens with incredible regularity. Given how scary monsters can be, it seems paradoxical that we keep making them. In fact, they are actually very important to us, and are deeply rooted in our evolutionary history and psychology.

Monsters are the fantastical descendants of our co-evolution with predatory animals: they are wired into our neurocircuitry. Snakes, for example, were some of our ancestors' first deadly predators. This scaly threat caused early primates to evolve specialised snake-responsive neurons in their visual cortices and large, visually dominated brains. You could say that snakes were monsters that helped make us. Just a small patch of scales is enough to suggest "snake" to a monkey or a human. Human babies who have never seen a snake before still respond uniquely to them.

This hardware, together with our capacity for symbolic representation, produced the serpentine monsters that abound in almost all traditions: dragons, hydras and more. It is why we get a thrill from watching *Snakes on a Plane* or the basilisk in *Harry Potter and the Chamber of Secrets*.



ELAINE KNOX

Likewise, the minds of many more recent hominins were shaped by the need to detect bears, lions and other mammalian predators in the tundra landscape of Europe during the last glacial period. As a vulnerable, naked ape in a landscape dominated by megafauna, we evolved to see predators in the merest shapes on the horizon, in the dark between tree trunks or in shadowy corners. With their long teeth and scythe-like claws, these mammals haunted our imaginations, appearing in cave paintings created over millennia. They might eventually have become the monsters of mythology.

There are psychological benefits to being frightened by monsters. When we listen to scary stories as kids, or watch films featuring horrific creatures, we experience acute fear. The foreboding, the jump scare, the all-out crisis: these activate the amygdala, the brain's fear centre. It revs up the fight-or-flight response, sending adrenaline coursing through our blood. In a safe context, the end of the story is followed by a drop in adrenaline and endorphin-fuelled relaxation. Such controlled bouts of fear might actually help us to manage chronic stress or increase our pain tolerance. It is why some people with anxiety enjoy watching true crime or horror films before bed. Others like to go skydiving or bungee jumping.

The monsters we create today for films, video games or books represent the greatest fears of our age: Godzilla threatening civilisation, fungi zombifying the entire human species, genetic experiments gone awry or aliens growing in our viscera. These creatures offer intense experiences of cultural catharsis. A case in point: during the early days of the covid-19 pandemic, horror fans reported lower levels of stress and fear about what was happening. Perhaps they had faced these monsters before, in films such as *28 Days Later* or *World War Z*. It is probably no coincidence that the series *The Last of Us* was such a hit after the height of the pandemic.

Monster media allows us to push otherwise-insurmountable anxieties away, externalising them into brutish, supernatural beings or extreme zombie pathogens, making normality appear relatively safer. It helps us exorcise our deepest fears. By understanding our monsters and why we make them, we can learn a great deal about what is going on under the surface of our minds and culture. ▮

Natalie Lawrence is a historian of science and author of *Enchanted Creatures: Our monsters and their meanings*

Future Chronicles

Feeding the world

We travel to the early 2030s, when a technological step change enabled us to produce all the food we needed without the use of animals. **Rowan Hooper** is our guide

Future Chronicles explores an imagined history of inventions and developments yet to come. Rowan Hooper is the podcast editor at *New Scientist* and author of *How to Spend a Trillion Dollars: The 10 global problems we can actually fix*. You can follow him on X @rowhoop

Invention
Star Trek-*style food replicators*

Timestamp
2030s

Tagline
The revolution that fed the world – and saved the planet

This column appears monthly. Up next week: Chanda Prescod-Weinstein

THE food revolution burst into the open in the early 2030s. Microbial processes were developed that allowed us to brew all the proteins we needed for our food without using animals, on a tiny fraction of the land, for less money. Such a disruptive technology hadn't been seen since the industrial revolution.

The dairy industry was the first to collapse. Milk is mostly water, sugar and a bit of fat. Two kinds of proteins, casein and whey, make up just 3.3 per cent of it. When these proteins were made on an industrial scale by genetically modified yeast, there was no need to devote land and infrastructure to farming cows, no need to clear rainforest to grow soya beans to feed cows, and no need to exploit our fellow mammals. Any dairy product could be made for a fraction of the cost.

Microbial production had begun, in the 20th century, with the churning out of vitamins such as riboflavin (vitamin B_2). The tech matured and, by 2023, essential omega fatty acids were made with engineered yeast. Many other proteins were made by engineered microbes, and when the processes were scaled up, they soon undercut their animal-derived equivalent. Leather, fish, eggs, meat could all be made far more efficiently.

Plant products were transformed too – even marijuana was better grown in vats. But the most important was palm oil. It had already been made by microbes and been used in beauty products by 2023, but as bioreactors improved and grew in output, industrial quantities were produced. The destruction caused by our appetite for palm oil was slowly dialled down: forests in Asia were restored and the orangutan saved from extinction. While environmental and ethical arguments had pushed for changes in farming for decades, it was the financial savings that drove this revolution.

Three main obstacles needed to be overcome to bring microbial food to the masses. Two were technical. First, food derived from microorganisms can have a high level of nucleic acids, especially RNA, which can pose a health risk. To get around this, microbes were engineered to self-purify. Second, the process of growing, fermenting and harvesting the microbes and their proteins had to be made to work on an industrial scale. A landmark moment was the opening in Finland of the first commercial factory producing microbial protein, in April 2024. Many others soon followed.

"The new food replicators allowed people to create previously unimagined flavour combinations"

The third obstacle was consumer acceptance. But microbially derived food products let consumers eat meat, fish, cheese, eggs and milk that tasted just like the real thing. This, plus the cheaper price, won over most sceptics.

Singapore was the first nation to approve microbial protein for food, in 2024. The US followed soon after and, by the end of 2025, the UK and the European Union had done the same. The revolution had begun.

Swapping meat from cows for proteins made by microbes was the single most important factor in saving the Amazon rainforest from destruction. Mathematical models had shown that swapping just a fifth of animal protein for that from microbes could halve deforestation rates, but by the early 2040s, more than half of the protein we consumed came from microbes. Vast areas of previously ranched and farmed land were allowed to rewild.

New developments in 3D printing, involving lasers and microbially derived ingredients, enabled the development of food replicators. Initially designed for astronauts living for extended periods on the moon or Mars, the replicators soon found their way into homes. While not quite up to the standard imagined in *Star Trek: The Next Generation*, a TV show from the late 20th century ("tea, Earl Grey, hot"), the new replicators allowed people to create previously unimagined foods and flavour combinations.

This technology, used alongside artificial intelligence, ushered in a golden era of delicious, plentiful, healthy food. Researchers in Cornwall, UK, developed what they called the Universal Pasty: a 3D-printed package containing a starter, main course and pudding in one pastry-wrapped delight. An Italian team created Tortellini Roulette: packages of pasta, each bursting with a delicious surprise ingredient. There was even a craze for Dodo Pie – which used proteins derived from the extinct flightless bird. Same with *T. rex* jerky. Meals could be customised for personal taste and health requirements.

The sci-fi replicators of *Star Trek* had been called a metaphor for the endpoint of the industrial revolution. The food replicators in fact ended the hegemony of industrial farming, the destruction it had been inflicting on our ecosystems, the suffering of billions of animals and the release of greenhouse gases from farming that had been driving the climate crisis. What it started was a food revolution that, just in time, saved the world. ▮

Events

NewScientist

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New Scientist video
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Going deeper

Martin Broen
Rizzoli

THE Yucatán peninsula in south-east Mexico is riddled with holes. When a giant asteroid struck Earth 66 million years ago near what is now the town of Chicxulub, the impact created a massive depression and caused fracturing of the porous limestone bedrock. Over millions of years, rainwater has dissolved the stone, creating underground rivers, caves and cenotes (sinkholes).

Photographer Martin Broen has explored 280 of the Yucatán's cenotes, atmospheric shots of which are collected in his book *Light in the Underworld*, out now in the US and on 17 September in the UK. This image, taken in 2020, shows the cave area of a cenote called Chan Aktun Ha (a Mayan name meaning "little water cave") in the state of Quintana Roo. Here, a cave diver is exploring among pristine stalactites and stalagmites.

"During rain showers in the Mexican jungle, water washes tannin from the vegetation into the cenotes, creating a tannic acid solution," says Broen. "These natural filters provide a surreal green, yellow or red atmosphere to the caverns."

The shallow caves of the Yucatán Peninsula have been flooded for the past 8000 years. "The more I dive, the more I discover the beauty and secrets of these caves, uncovering unique fossils of extinct megafauna, indications of the first Palaeo-Americans, and Mayan artefacts," says Broen.

But, he adds, cenotes aren't just a window into the past but "the veins that carry all fresh water in the region". With pollution, deforestation and development all a threat, Broen hopes his photos can help people care about what lies beneath their feet.

Graeme Green

Race to the top

How have AI models like ChatGPT changed the world, and who were their architects? A riveting new book takes an inside look, says **Alex Wilkins**

REUTERS/AMIR COHEN

Tel Aviv University before a talk from OpenAI CEO Sam Altman in June 2023

Book

Supremacy

Parmy Olson

Macmillan Business (UK); St Martin's Press (US)

FOR most people, ChatGPT appeared to materialise out of thin air. Within weeks of OpenAI's quiet launch of the AI chatbot, it had become the fastest-growing app of all time and, almost two years later, it is nearly as well known as Google or Facebook. In the meantime, companies worldwide have gone gaga for the technology, with little time to pause to consider the wider societal consequences. So how did we get here and who was responsible?

Much of the praise (or blame, depending on how you feel about AI) lies with two men, argues journalist Parmy Olson in her book *Supremacy: AI, ChatGPT and the race that will change the world*. Sam Altman and Demis Hassabis, respectively the CEOs of OpenAI and London-based DeepMind, became involved with AI in very different ways, but their stories quickly became intertwined.

Altman, a Silicon Valley boy wonder, rose through the ranks of California's start-up scene before setting his sights on what he viewed as the world-changing potential of AI. Hassabis, a child chess prodigy who flitted between the British video game industry and academia, was drawn to AI for different reasons, seeing it as a way to uncover the secrets of the universe.

Despite these differences, they found themselves in similar positions, steering AI research labs towards the ill-defined goal of "artificial general intelligence" (AGI). Both men started out with lofty ethical principles, promising to shepherd their AI systems for the public good and keep them out of the hands of profit-driven big tech companies. Both ended up financially entangled with those same companies, with Microsoft's backing of OpenAI and Google's purchase of Deepmind.

It's a riveting tale and Olson is a compelling storyteller, drawing on the high-level access she has to both men, along with other figures in the story, thanks to her job as a tech columnist at Bloomberg Opinion. Neither Altman nor Hassabis comes off too badly in Olson's telling, and she clearly has some sympathy for the complex web of philosophical and political movements they find themselves in as part of the AI field, like effective altruism, the "earn to give" ideology that disgraced crypto mogul Sam Bankman-Fried was famously a fan of.

"One of the perils of writing about AI is that the tech progresses so fast that you risk becoming outdated"

But this isn't a hagiography either, and Olson is clear about the dangers that OpenAI and Deepmind have, in her view, conveniently ignored in an effort to push their technology out to the world so quickly and be first to claim the glory. Many of these will sound familiar – "hallucinating" made-up information, propagating the bias of the data they were trained on, generating offensive content – but Olson gives prominent voice to the researchers, nearly all women, who first raised many of these issues, and illustrates well how they were nearly universally ignored by their bosses, who were mostly men.

One of the perils of writing about AI is that the technology progresses so fast that anything you write is at risk of becoming instantly outdated. Olson largely avoids this by focusing on the story before ChatGPT, but there are times she must make an attempt to be as up-to-date as possible. Towards the end of the book, she covers more recent developments, such as the failed ousting of Altman by the OpenAI board last November, which still feels exciting, and the launch of tools like image generators and coding assistants, which feels less interesting and tangential to the earlier narrative of the book.

The story that has developed since Olson penned her last words, in March this year, has also been one of growing scepticism around whether AI models may have begun to approach a wall. OpenAI's long-anticipated GPT-5 model is seen as a make-or-break moment for the industry, and whether it significantly moves the needle towards AGI, as either OpenAI or Deepmind have defined it, will dictate to a large extent whether the AI bubble will keep growing.

The subtitle of Olson's book, "the race that will change the world", makes that scenario sound like a certainty. But there is still a chance that our AI models might not get much more advanced than they are today, and these past two years will seem like an anomaly, rather than the norm. ▮

New Scientist Live
Generation pup
Learn all about canine science from Rachel Casey on 12 October **newscientist.com/nslmag**

The power of the dog

What is it like to be a dog? And what can we learn from them? A philospher's take is full of insights, finds **Abigail Beall**

Book
The Happiness of Dogs
Mark Rowlands
Granta Books

DO YOU spend a large chunk of your day looking at your dog, asking questions like "what do you think he is thinking right now?" Or "does she understand how much I love her?" If that sounds familiar, then a new book by philosopher Mark Rowlands may be just the thing.

The Happiness of Dogs: Why the unexamined life is most worth living **is a fascinating take on what it is like to live like a dog. It touches on the unique bond between humans and their companions, tackles such big questions as the meaning of life and goes on to explore experiments into animal consciousness.**

I learned a great deal about how dogs experience the world and why traditional tests of consciousness might be flawed. Take the classic question of whether animals recognise themselves in the mirror – something manta rays

Unlike humans, dogs may know what they know through living rather than through thinking

and wrasse fish seem to be able to do, while dogs struggle. Rowlands reframes this to suggest it doesn't mean a dog is less self-aware than a wrasse, rather that it navigates the world in a different way. He suggests a dog might not inspect its reflection because "it doesn't care about how it looks in a mirror" – something I know I would rather spend less time caring about.

That said, I found the book challenging at times. Particularly tricky were the sections that dived deep into philosophy, which make up a large part of it. While this is to be expected from a philosopher, it can be a bit much for someone unaccustomed to reading about (or even thinking about) the question of what makes life worth living.

Overall, though, I felt that Rowlands made the philosophy digestible by sprinkling in chapters on animal consciousness and plenty of tales from his own life and the canines that have been a part of it. These latter sections were the ones I found most enjoyable, especially due to Rowlands's unusual track record. He spent years living with a wolf, which he wrote about in *The Philosopher and the Wolf*.

I also loved anecdotes about Rowlands's beloved dog, Shadow, chasing iguanas along the canal near his home or getting excited about such trivial daily routines as jumping in the car to pick Rowlands's son up from school. This is probably because I recognise my own dogs in them – whether it is my greedy Jack, who is full of joy and surprise every day when I feed him his dinner, or my precious Peanut, who trembles with fear when she leaves the house but comes alive when running along an empty beach.

As an owner of a very anxious dog, some of the sweeping statements about dogs and their joy were hard to swallow. Rowlands writes that "for a dog, happiness comes effortlessly", and he talks about "unbridled happiness – in their love of life and their utter commitment to their actions". Of course, this is the case for a dog with a happy life. But I couldn't help but think this isn't true for all dogs.

Peanut, for example, was born on the streets, abandoned when she was a few days old and spent the first two years of her life in a kennels. Six years later, she does experience joy every day, when we take her to her favourite field or she is playing with her housemate. But plenty of her time is also spent in fear, when there are loud, unexpected noises, such as a van driving past or when I rustle a plastic bag. In these moments, she seems to embody a phrase Rowlands uses to describe humans, "uneasy creatures, never quite at home in the world or even in our own skins".

In any event, the take-home message from *The Happiness of Dogs* is that we humans should be more dog. Instead of reflecting on and endlessly wondering about everything, we should live more in the moment. "What we know, if we know anything, we know through thinking," writes Rowlands. "Dogs in comparison know through living."

SHUTTERSTOCK/TOM WANG

New Scientist *recommends*

Bethan Ackerley
Subeditor
London, UK

I have been watching **Supacell** on Netflix, a superhero drama that follows five Black south Londoners who suddenly develop superpowers. I won't spoil the exact reason why, but it is to do with their genes.

Series creator Rapman (aka Andrew Onwubolu) was a fan of comparable US drama *Heroes*. I was too, so had to watch the new show. It is also about ordinary people, such as nurse Sabrina (Nadine Mills, pictured), facing extraordinary situations. My favourite was Andre (Eric Kofi-Abrefa), who is tempted to misuse his superstrength to provide for his son.

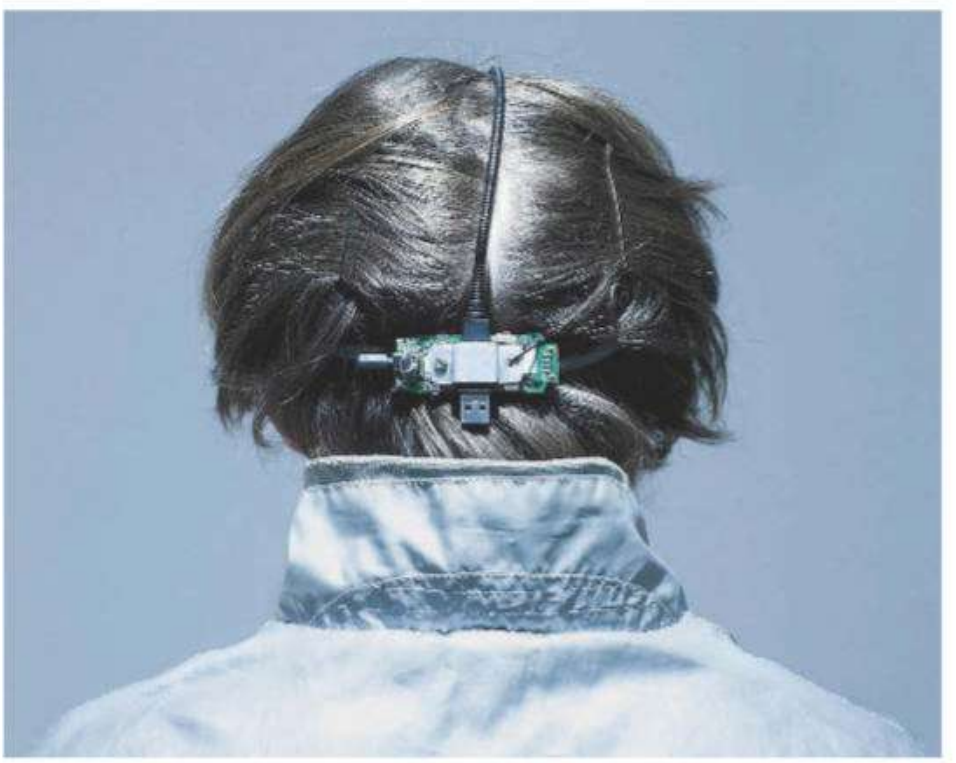
I have also read **A Woman's View** by Jeanine Basinger, about the contradictory, often-subversive themes of the "woman's picture". She argues that female fans of these 1930s, 40s and 50s movies made a sly bargain: they could spend 85 minutes watching Joan Crawford live out their fantasies of power, misbehaviour and sex if they endured 5 minutes of conservative moralising. I'd take that deal, wouldn't you?

NETFLIX

The film column

A new sense Neil Harbisson was completely colour blind, but after a sound generator was attached to his skull, he could "hear" colour. *Cyborg: A documentary* tells his story, but could have used more bite, says **Simon Ings**

Simon Ings is a novelist and science writer. Follow him on X @simonings



SIDEWAYS FILM

The back of Neil Harbisson's head and his sound generator

NEIL HARBISSON studied music composition at Dartington College of Arts in the UK. He was born with achromatopsia, so is unable to perceive colour of any kind. Not one to ignore a challenge, in 2003 Harbisson recruited product designer Adam Montandon to build him a head-mounted rig that turns colours into musical notes that he can listen to via earphones.

Now in his 40s, Harbisson has evolved. The sound generator and an attached camera on a pencil-thin stalk are permanently fused to the back of his skull. He hears colours through bone conduction.

If, indeed, "hears" is the word. Watching Carey Born's *Cyborg: A documentary*, we sometimes catch Harbisson talking intelligently about the senses. He doesn't hear colour so much as see it, because his visual cortex interprets the information directly, much as practised Braille readers don't go through a stage of interpreting sensations of touch. His colour organ is startling: what is that antenna on the back of that chap's head? But Harbisson is used to it, and his brain treats its input like any other visual information.

Body modification in art has a long, rather vexed history. I recall performance artist Stelarc suspended from flesh hooks, pronouncing on the body's obsolescence. He doesn't do that sort of thing now. As he nears 80, you can declare victory over the flesh as much as you like: time gets the last laugh.

"It is endearingly old-fashioned – as though the body's plasticity wasn't already a burning social issue"

The way Harbisson hacked his own perception leaves him with very little to do but talk about his experiences. He can't demonstrate them, unlike his partner, Moon Ribas. The dancer-choreographer has a vibrating, internet-enabled gadget in her left arm that tells her how to respond to real-time earthquake data. The bigger the vibrations, the stronger the quake, and this guides her dancing.

Harbisson, however, is stuck explaining what it is like to have friends transmit the colours of an Australian sunset to the back of his skull. Using the same rig he has, they send a signal that generates a tone that is a specific colour to him. To which one radio show guest objects: couldn't they just send him a postcard instead?

Born never digs into this very sensible question. It is a pity. Harbisson says he weathered months-long headaches and episodes of depression in an effort to extend his senses, but all outsiders care about is the tech.

A recent novelty created by Harbisson and his collaborators is a headband that tells the time by heating spots on your skull. Obviously, a watch offers a more accurate measure. Less obviously, the device is meant to create a new sense in its wearer, an embodied, pre-conscious awareness of solar-planetary motion. The tech is fun, but what matters is the idea.

I find it slightly irksome to explain Harbisson's work when he hardly bothers. For over 20 years, he has offered his audience what they now expect: a ringing endorsement of transhumanism, the philosophy that would have us treat our bodies as malleable meat.

Harbisson and Ribas co-created the Cyborg Foundation and the Transpecies Society to give a voice to cyborgs and others with non-human identities. An endearingly old-fashioned approach, it is as though the body's plasticity wasn't already a burning social issue, and a weapon in our culture wars.

I wish Born had challenged her subject. Penetrate their shell of schooled ego and you may find conceptual artists have a surprising amount to say. ▮

Film

Cyborg: A documentary

Carey Born

First Born Films

In UK cinemas on 20 September; US to be announced

Simon also recommends...

Films

X: The Man with the X-Ray Eyes

Roger Corman

Streaming

Ray Milland stares into the universe and regrets it in one of horror director Corman's more existential forays.

Crimes of the Future

David Cronenberg

Prime Video

Viggo Mortensen and Léa Seydoux perform artistic surgeries in a future that thinks it has mastered evolution. You can almost hear Cronenberg chuckling.

Editor's pick

We still lack a fundamental explanation for morality

31 August, p 28

From Andrew Whiteley, Consett, County Durham, UK

Webb Keane's anthropological account of morality in his book *Animals, Robots, Gods* encounters the familiar problem experienced by reductive explanations of the moral faculty. However sophisticated the concepts deployed, morality is explained away as essentially a social construct, a matter of social conditioning. I am given no reason, ultimately, why I must do the right thing, why I must not pursue my interests at the expense of others. What truly lies at the heart of the moral sense is unaccounted for.

Exploring the latest mystery of Stonehenge

24 August, p 16

From Richard Deacon, London, UK

While I remain in awe of the detective work that has gone into suggesting a Scottish origin for the altar stone at Stonehenge's centre, I remain dumbfounded by the belief that it was human agency that brought it there.

Surely a far more believable story is that the stone was there anyway somehow and our Bronze Age ancestors recognised its difference – its strangeness – and therefore its possible potency, so began using it as a spiritual focus? The construction of Stonehenge around it followed from this.

From Robert Senior, Uppingham, Rutland, UK

Acquiring objects from abroad, particularly if they have cultural significance, is something humans like to do. Stones, whether gems or edifices, are particularly popular.

Might the altar stone have been acquired in the same way? We now know that it must have come from an area of north-east Scotland. Orkney is at the centre of that area. The Ring of Brodgar on the main island of Orkney is a circle of standing stones that was made by a thriving Neolithic settlement.

That ring was there when Stonehenge was being built, and today it has 20 stones missing. Your article suggests the altar stone would have been brought to Stonehenge by sea: where better to find a craft and a crew to transport it than in an island community?

From Fred White, Nottingham, UK

The altar stone isn't the only Scottish connection to Stonehenge. Isotopic analysis of pig teeth near Stonehenge found they had been brought from the Orkney islands for feasting.

An engineer's vote for the cynical approach

17 August, p 36

From Miles Fidelman, Acton, Massachusetts, US

In engineering, cynicism is a very practical way to approach big challenges. You must assume that anything that can go wrong will go wrong and proceed accordingly. Only after everything that can go wrong has gone wrong and you have cleaned up the mess can you get on with making things go right.

Caffeine: great for us, not so good for farms

24 August, p 36

From John Hedger, Dundonnell, Ross and Cromarty, UK

I was delighted to find that moderate consumption of caffeine is good for *Homo sapiens*. It may not be for some other species: I was once told of experiments on the use of waste pulp from coffee berry processing as cattle feed in Mexico in the 1970s. Although this was full of apparently useful sugar and protein and was eaten with enthusiasm, the cattle inexplicably failed to gain weight.

The problem was solved by an astute student (my informant) who got out of the lab and spent a few days cattle-watching. The test group spent their days excitedly running and jumping, enjoying a caffeine high rather than getting down to the serious business of eating grass.

These financial trades are bad enough already

17 August, p 14

From Sam Edge, Ringwood, Hampshire, UK

High-frequency trading already demonstrates that the financial markets are nothing but a shell game profiting only the already ultra-rich and causing misery for the rest when they go off the rails. Making such trading even more volatile with quantum technology will only cause harm.

Delving into the maths behind the latest AIs

27 July, p 28

From Elizabeth Hembree, Lexington, Virginia, US

In your review of Anil Ananthaswamy's book *Why Machines Learn*, I was astonished to read his statement that the mathematics behind AI is simple, "the kind one learns in high school or early college".

This may be true of a basic model, but not for ChatGPT, Claude and other neural network-based models, which involve billions of parameters and multiple dimensions. The maths is stochastic probability theory, stochastic calculus and linear algebra often not encountered until the postgraduate level.

Nature will have occupied all the levels of reality

10 August, p 18

From John Davidson, Knighton on Teme, Worcestershire, UK

It is fascinating to consider the possibilities of quantum biology, but surely its existence would be no great surprise. It seems to me that nature is already functioning happily at all the "levels" we humans think we can discern, and many more we have yet to identify.

Surely molecules, atoms, subatomic particles, the quantum world and the microdynamics of space, etc., are all aspects of one natural system, functioning as a whole, and the various so-called levels are all human constructs – a useful analysis or a window onto something we don't fully understand, part of a whole we have yet to comprehend?

A simple solution to food's climate impact

17 August, p 13

From John Kitchen, Kettering, Northamptonshire, UK

You report the growing impact of emissions from food production on the climate. The only way to avoid this kind of damage is for every person to limit their meat intake to less than 200 grams per week. This is a fraction of what many people now eat. We do need dietary vitamin B_{12} and animal products are rich in this, but B_{12} supplements and fortification are plentiful these days.

No matter what the agricultural industry says or does, unless we eat far less meat, we will destroy our environment. ▮

For the record

▮ A 100-nanometre glass bead is a thousandth of the width of a human hair (31 August, p 16).

▮ Orkney is in Scotland, off the mainland (24 August, p 47).

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Fresh insight into what causes obsessive-compulsive disorder is paving the way to new treatments, discovers **Anthea Rowan**

Rethinking OCD

WHEN my daughter was young, she washed her hands a lot. We might have poked what we thought was gentle fun at her, saying she was "a little bit OCD". Later, she began to disclose "bad thoughts", which I assumed were the typical products of a child's imagination. I told her we all had thoughts like that, and if we ignored them, they went away.

Hers didn't. At 21, they were out of control and out of proportion to anything like reality. She was diagnosed with obsessive-compulsive disorder and I finally realised there was nothing "a little bit" about this condition.

OCD is complex and commonly misunderstood, with a limited number of treatment options. But in recent years, the mechanisms in the brain and body that drive it are finally being pinned down, revealing an elaborate picture involving genetics, various brain networks, the immune system and even the bacteria in our gut. In turn, this growing understanding is opening up new possibilities of tackling this life-sabotaging condition.

Around the world, between 1 and 3 per cent of people are estimated to have OCD, which typically begins during adolescence or early adulthood. As its name suggests, it is characterised by obsessions – or intrusive thoughts – and compulsions, which are habits you can't stop. "Compulsive thoughts capture attention and take over because they've become a compulsive habit," says Barbara Sahakian at the University of Cambridge.

The obsessions are unwanted ideas, images or impulses that dominate people's thoughts and defy efforts to control them. They typically involve themes of danger or harm, such as excessive fears about contamination, an extreme concern with order and symmetry or worries about losing important things.

Compulsions can take many forms: excessive washing, lock checking or superstitious behaviours like touching an object a certain number of times to prevent something bad happening. "The symptoms are very disabling and unpleasant," says Trevor Robbins, also at the University of Cambridge.

I have witnessed the physical manifestation of my daughter's thought process on a loop in her repeated hand-washing – yet the intrusive thoughts aren't silenced by soap and water or reassurance that thoughts are just thoughts.

This highlights one of the problems with our understanding of OCD, because obsessive thoughts and compulsive actions are part of everyday life, to some degree. We go back to check that we did indeed lock the front door, and can't stop our mind wandering to the stressful event coming up next week. Indeed, many symptoms of OCD represent distortions of useful behaviours or defence mechanisms – such as avoiding contaminated substances or checking that a fire is out – intended to ensure safety.

But when obsessive thoughts become frequent or intense, or compulsive rituals become so prominent that they interfere

BRETT RYDER

with an individual's functioning, that is when a diagnosis of OCD is made. In severe cases, people may not be able to leave their home, as they are performing their rituals for as long as 12 hours a day, says Robbins.

Currently, the front-line treatment for OCD is a specialised form of cognitive behavioural therapy (CBT) called exposure and response prevention, in which the individual is gradually exposed to situations that trigger them and learns ways to cope with their distress. Drugs called selective serotonin reuptake inhibitors (SSRIs), commonly used to treat depression and anxiety, can also be used. But around a third of people with OCD don't respond to these, so the hunt is on for alternatives.

Brain loops

One line of enquiry that researchers have pursued since the 1990s is to try to understand the brain mechanisms that drive OCD. An increasingly clear picture is emerging of its underlying circuitry. This research has highlighted the importance of certain neuronal networks that help prioritise information and decide which bits we should act on. Known as frontostriatal loops, these connect the front of the outermost part of the brain, the cortex, with an inner region called the striatum (see "OCD brain networks", page 35).

One of these loops is related to goal-directed behaviour, where we deliberately weigh up information and decide on certain actions to achieve a particular objective. Another is involved with our habit system, where we carry out actions automatically. There is constant interplay between these systems, with the goal-directed network able to inhibit the habit ones.

Both systems can be impaired in OCD, says Naomi Fineberg at the University of Hertfordshire, UK. "There's poor inhibitory control." For instance, under-connectivity in the goal-directed loop and hyper-connectivity in the habit network are both associated with stronger OCD symptoms.

A third loop acts as a control circuit that arbitrates between the goal-directed and habit systems and allocates control "This mainly enables flexible switching between the goal-directed and the habit system," says Robbins. "If this system is impaired, which also appears to be the case in OCD, then you will have a ›

BASAK GURBUZ DERMAN/GETTY IMAGES

scenario where it is difficult to disengage from the habit system, leading to repetitive behaviour, which may be a driver of compulsive behaviour."

The importance of this arbitration loop was highlighted earlier this year in a study by Jun Soo Kwon at Seoul National University, South Korea, and his colleagues, in which people with and without OCD had their brains scanned while carrying out cognitive tests. The researchers found that reduced connectivity in the brain network involved with arbitration was linked to the severity of compulsive symptoms.

Another piece of the puzzle of OCD in the brain is the role of the neurotransmitters that drive and direct the activity in neural networks. A major leap forward in our understanding of this came last year in a study that looked at the levels of two key neurotransmitters in the brains of people with and without OCD: glutamate, an "excitatory" neurotransmitter that enhances communication between neurons, and GABA, which dampens it.

Using a powerful scanning technique, Marjan Biria, who is now at University College London, Robbins and their colleagues focused on two specific brain regions: the anterior cingulate cortex and the supplementary motor area, which are both involved in controlling the balance between conscious goals and more automatic habits. They found that people with OCD had higher levels of glutamate and lower levels of GABA in the anterior cingulate cortex, compared with people who don't have the condition.

The study also found that the severity of OCD symptoms and a tendency towards compulsive behaviour were related to higher glutamate levels in the supplementary motor area. The dominance of excitatory neurotransmitters in these regions may make them hyperactive, which, in turn, allows compulsive behaviour to dominate.

These findings lend weight to a surprising alternative view of OCD that has emerged over the past decade. The traditional explanation for the condition is that obsessive thoughts drive compulsive rituals, which are carried out to control or reduce distress. The alternative hypothesis turns this on its head: the idea is that obsessions may arise as a post-hoc rationalisation of compulsive behaviour. In other words, compulsive habits may be the driver of the irrational beliefs and worries, not the other way round.

Crucial evidence for this came from a 2014 study in which participants with and without OCD were trained to develop new habits in the lab. To avoid getting a shock to their wrist, they pressed a pedal when they saw a square on a computer screen. Later, the shocker was disconnected from their wrist, so there was no longer a need to press the pedal to avoid pain. Strikingly, those with OCD – but not those without – continued to press on the pedal when they saw the square, even though they said they knew it could no longer harm them.

When questioned about their persistence in pressing the pedal, some volunteers with OCD invented explanations for their behaviour such as "I thought it could still shock me somehow" even though they earlier said that they knew they wouldn't be hurt. One rationale for this disconnect is that when we carry out an action that no longer makes sense, our brains can invent a story that makes our behaviour seem more logical.

"Compulsive thoughts take over because they have become a compulsive habit"

This still begs the question of why some people are more prone to OCD than others. Here, too, the underlying factors are becoming clearer. We have long known that genetics plays a strong part, because OCD tends to run in families, with the immediate relatives of affected individuals having a four to eight times higher risk of developing the condition.

In fact, half of the risk of developing OCD is down to our genes. A paper from March that has yet to be peer-reviewed pinpoints some of the finer details. This examined the genomes of nearly 40,000 people with OCD and identified 15 genetic signatures associated with the condition, including ones for proteins that influence brain function and development. Intriguingly, one of the other signatures identified was associated with the genes for the major histocompatibility complex, a region of DNA that plays an important role in the immune system and has also been linked to other mental health conditions such as schizophrenia and bipolar disorder.

This finding fits with a growing body of evidence that the immune system is one of the factors driving OCD. It seems to have this effect by influencing certain brain networks that, in turn, enhance compulsive behaviours. A case in point is two related conditions called PANS and PANDAS in which children can suddenly develop OCD symptoms, anxiety or tics seemingly in response to infection.

"In PANS/PANDAS, severe OCD symptoms can present within hours and from nowhere," says Fulvio D'Acquisto at the University of Roehampton, London. It appears that an immune reaction may cause inflammation and impair a brain region heavily implicated in OCD called the basal ganglia, of which the striatum is part.

Further support for the role of the immune system in OCD comes from the 2023 discovery by a team of researchers, including D'Acquisto,

Going back to check a lock repeatedly is a common symptom of OCD

Do microbes cause OCD?

Evidence is mounting that the microbes in our gut play an important role in mental health conditions, and new research is revealing that this is the case for obsessive-compulsive disorder too.

Key evidence comes from a study published this year, in which a team at Shanghai Jiao Tong University, China, transplanted faecal gut microbiota from humans with OCD into mice. Two weeks later, the mice began to exhibit repetitive behaviours and signs of anxiety compared with animals that didn't receive a transplant.

The researchers also found inflammation in a key brain area implicated in OCD called the medial prefrontal cortex, probably due to the accumulation of a substance called succinic acid driven by the proliferation of transplanted microbes.

This not only indicates that gut microbes might be a causative factor in OCD, but opens up potential routes to treating the condition through diet or manipulation of the types of microbes in our digestive system.

that people with the condition have increased activity levels in a gene for a protein produced by immune cells called immuno-moodulin, or Imood.

D'Acquisto and his colleagues had found this protein by chance a few years earlier while working on mice that exhibited high levels of compulsive digging, and discovered that this behaviour was linked to high levels of Imood. Their soon-to-be published research will set out a proposed mechanism for the protein's effect: an infection leads to temporary increases in Imood, which then accumulates in the brain, altering the functioning of neuronal cells, says D'Acquisto.

What's more, antibodies against Imood reduce the compulsive behaviours in mice, raising the possibility that they might work in humans too. Efforts to develop a human version of the Imood antibody are currently under way, with the aim of testing them as potential new treatments for OCD.

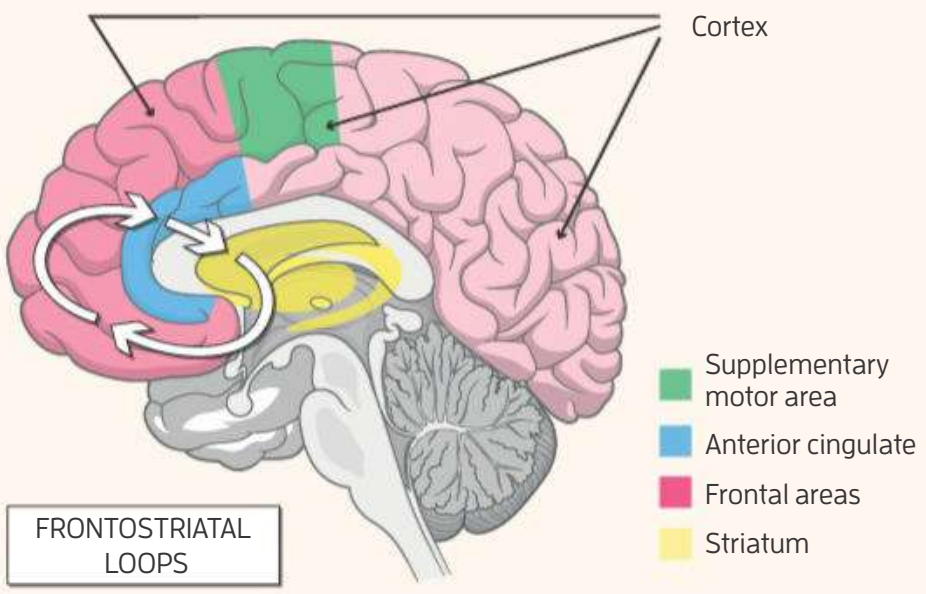
But this is just one of many avenues being explored in the hunt for new ways to tackle the condition. These include brain stimulation techniques, phone apps and even changes to diet, as there is emerging evidence that gut microbes play a part in the condition too (see "Do microbes cause OCD?", above).

One of the many new ideas is to use ketamine. This anaesthetic and rave drug causes feelings of disassociation, and is undergoing a surprising conversion to being used to treat brain and mental health conditions. For instance, a randomised controlled trial carried out by Carolyn Rodriguez at Stanford University in California and her colleagues found that taking ketamine resulted in a rapid improvement in OCD symptoms. In a study due to be published soon, the researchers found that a single intravenous infusion relieves symptoms for about three weeks. Rodriguez is now exploring the biochemical mechanisms through which this drug works.

However, the addictive nature of ketamine and its side effects mean it is no magic bullet. "These things give me pause. I'm not advocating people with OCD rush to use ketamine," says Rodriguez, who is a strong proponent of CBT treatment for OCD. To use an analogy, if a person broke their arm, they would need a cast to support it in recovery, she says. "I think of CBT as the plaster cast ›

OCD brain networks

One underlying cause of obsessive-compulsive disorder is alterations to neuronal pathways called frontostriatal loops. We also know that neurotransmitter imbalances in two brain regions, the anterior cingulate cortex and the supplementary motor area, are linked to the condition.



SOURCE: OCDANDTHEBRAIN.COM

MARC BRUXELLE/ALAMY

A patient undergoing transcranial magnetic stimulation, which can help alleviate OCD

"The psychedelic drug psilocybin is in clinical trials for treating OCD"

and ketamine, in the short term, to alleviate pain while doctors cast the break."

Ketamine is thought to work because it increases neuroplasticity – the brain's ability to remodel itself – and, in so doing, it loosens the characteristically rigid thinking that accompanies OCD and makes those with the condition more receptive to CBT.

For similar reasons, the psychedelic drug psilocybin – the active ingredient in magic mushrooms – is also in clinical trials for OCD in the UK and the US. In the body, it is converted into a molecule that binds to a specific receptor in the brain for the neurotransmitter serotonin, so it can act in similar ways to SSRIs and, in turn, may help unstick thought patterns. "If you boost serotonin, it makes you more flexible," says Robbins.

We are also seeking fresh treatments by looking at existing drugs designed to treat other mental health conditions, especially those that work on the brain's glutamate pathways, which we now know are implicated in OCD. A case in point is the drug riluzole, approved by the US Food and Drug Administration (FDA) to treat motor neuron disease. Early studies found it helpful in treating OCD that is resistant to treatment with SSRIs and CBT.

Now, the pharmaceutical company Biohaven is working to develop a related drug, troriluzole, with fewer side effects. It is in a phase III trial in humans and is, according to Rodriguez, "the closest we've been since the 1990s to a new FDA-approved drug" for OCD.

New treatments are sorely needed because, for the 10 per cent of people with severe OCD whose symptoms don't respond to CBT or SSRIs, invasive surgical procedures are currently the main alternative. These include anterior cingulotomy, when a permanent lesion is made in area deep in the brain involved with OCD behaviours. Alternatively, deep brain stimulation (DBS), where thin electrodes are inserted into this part of the brain to deliver electrical currents, is a less permanent way to mimic these lesions and disrupt information flow.

Brain stimulation

Around two-thirds of people receiving DBS for OCD see a marked reduction in symptoms. However, it is a last-resort treatment as it is invasive and comes with risks such as infection, seizures or bleeding. But this may change if a newly developed non-surgical technique to stimulate neural activity deep in the brain called transcranial temporal interference stimulation (TTIS) proves to be a viable alternative. In this, electrodes attached to the scalp deliver signals at different frequencies to a particular deep brain region.

When these signals interfere with each other, they alter neural activity. A randomised trial in May found this technique could selectively target the striatum.

Meanwhile, a number of other non-invasive techniques to alter the neural pathways in outer parts of the brain – through magnetic or electrical stimulation – are becoming increasingly common, with the first such device approved by the FDA for OCD in 2017.

Just like for TTIS, these devices are composed of electrodes or electromagnetic coils that are placed on top of the skull. The effect – felt as a buzz – can be tailored to the brain circuitry of the individual, something that can be done with ever greater precision now that we have a clearer understanding of the brain networks associated with OCD symptoms.

A 2023 meta-analysis of 25 trials of so-called transcranial magnetic stimulation (TMS) found that it "exhibited a moderate therapeutic effect... on OCD symptom severity". The effects are small, says Fineberg, but it has value "perhaps in helping to loosen the brain up so you can do your CBT".

However, Robbins is more optimistic about the potential of TMS, especially since studies are under way to establish the best brain areas to target and the optimum doses for alleviation of symptoms. "The exciting thing about TMS is that it adjusts the so-called excitatory/inhibitory balance in the cortex, which we've recently shown is affected in OCD," he says.

The upshot of all these investigations into the mechanisms underlying OCD is that, in future, clinicians should have some much-needed new tools to treat this distressing and sometimes intractable condition. "OCD is not a neurodegenerative disease where you're losing the brain," says Robbins. "It's just that the brain has been modulated – it's not in the right state. I think it could be made to function better." Rodriguez is also optimistic for the future. "I'm so hopeful for the patients I have now for when they are older," she says. "The technology is coming on in leaps and bounds."

When I ask my daughter what she thinks about these new possibilities she, too, is hopeful. "Knowing there may be things within my reach that can ease OCD symptoms is really helpful," she says. "It makes me feel more in control." ▮

Anthea Rowan is a freelance writer and author of *A Silent Tsunami: Swimming against the tide of my mother's dementia*

ADOBE STOCK

The ultimate timepiece

The most precise clock ever built could transform our understanding of the universe, finds **Lyndie Chiou**

EKKEHARD PEIK is a clock-maker. But instead of spending his days looking at tiny cogs and springs through a magnifying glass, the tools of his trade are powerful lasers, wires and, occasionally, radioactive atoms. Peik, director of the German metrology institute (PTB), is one of a handful of physicists who have spent the best part of three decades trying to make the most accurate timepiece in the universe.

Since the 1950s, researchers have been constructing atomic clocks, the very best of which are now so accurate they only lose a second in around 31 billion years. But these are about to be replaced by a new model: the nuclear clock.

This promises to outperform its atomic counterparts both in terms of precision and accuracy. A nuclear clock would, in principle, only drop a second every 300 billion years. Why, you might ask, would we ever need something with such mind-blowing precision? Because it will be used for something much more exciting than simply telling the time. Nuclear clocks could help probe some of the deepest mysteries of the universe, including the nature of dark matter and some of the elusive fundamental forces that shape our cosmos.

The tick of today's atomic clocks is the result of electrons that oscillate between a pair of shells around the nucleus of an atom. The transitions between these shells are driven by shining lasers at the atoms involved at just the right frequency to match that of the oscillations, a state that is known as resonance. This resonant frequency, the number of oscillations of light per second, sets the tempo of the clock.

In the case of atomic clocks, the number of oscillations each second is extremely stable, so we can use them as very precise timekeepers. The best atomic clocks use ytterbium or strontium atoms and have ultra stable resonances. This exceptional accuracy enables GPS, keeps financial systems in check and allows us to test the limits of fundamental laws of physics, like the time dilation predicted by Albert Einstein's general theory of relativity.

But atomic clocks have limitations. Electrons form the outer part of an atom, and as such they are vulnerable to interference from electric and magnetic fields that can cause the resonances to shift. "What limits these clocks is that in the lab you have to control all the environmental parameters – the smallest magnetic fields, the smallest electric fields, everything," says Sandro Kraemer, a physicist at KU Leuven, a university in Belgium. "So, in practice, we're always fighting that."

In 1996, Eugene Tkalya, a physicist at Moscow State University, realised there was a better solution. Instead of using electrons on the edge of an atom, a neutron moving between two energy levels inside an atom could be the basis of a clock. There were clear reasons such a device would outperform an atomic clock. While the electron shells are affected by stray electric and magnetic fields, neutrons are impervious to these forces. Instead, they are only affected by the strong nuclear force, which interacts over extremely short distances – less than the width of an atom. A nuclear clock would measure time with orders of magnitude more precision than an atomic clock.

For most atomic nuclei, driving such a resonance would require a laser more powerful than we have yet invented. There is an exception though – the radioactive element thorium-229 (Th-229). This needs an unusually low amount of energy to create its oscillation. "It's still high compared to what people typically use nowadays in atomic clocks, ›

New Scientist Live

The mysterious nature of charge

Frank Close explores the dynamics of the subatomic world on 12 October **newscientist.com/nslmag**

but it's so low that one could imagine driving this with a laser," says Eric Hudson, a physicist at the University of California, Los Angeles.

Physicists set to work to be the first to achieve this neutron oscillation. The initial, and biggest, hurdle was that no one knew exactly what energy was required. Only by knowing this very precisely could a laser be tuned to produce the resonance. This value couldn't be calculated, only determined through careful experimentation.

Probing the strong force

The reason for this lies in the strong nuclear force. As the name suggests, it is the strongest of the fundamental forces, but only over the shortest distances. It confines fundamental particles called quarks together in a bubble to make protons and neutrons. But move a tad outside the bubble, and the strong force peters out to nothing.

To this day, the physics behind the strong nuclear force makes it extremely difficult to make practical calculations of the entire nucleus. "There is a pretty good model of strong interaction in the standard model [of particle physics]," says Kraemer. "However, to describe a whole nucleus, there are so many potential interactions." As a rule, in such cases, physicists rely on approximations. Yet, even with these simplifications, our largest supercomputers don't have enough capacity to calculate the physics of heavy atoms like Th-229. This means values related to the inner workings of the nucleus, like the Th-229 resonance, must be found by trial and error.

The number of possibilities was so large that finding the right one was like looking for a needle in a haystack. Over several years, starting in 2009, physicists like Bret Beck at the Lawrence Livermore National Laboratory in California narrowed down the Th-229 transition energy to smaller and smaller ranges. Then, Hudson hit on a novel approach. Instead of measuring the transition from a single Th-229 atom, as others had been doing, he proposed a way to boost the signal by embedding billions of atoms into crystals. This would finally allow a more precise measurement of the energy required, and make a nuclear clock feasible.

Fast-forward to 2023, and physicists working at CERN, the particle physics laboratory near Geneva, Switzerland, narrowed down the uncertainty in the energy gap even further. On the back of this, both Hudson's and Peik's groups refocused their search efforts to this much narrower region. Peik's group started scanning from the upper end of the new range, while Hudson's started from the lower end.

Then, one day in November 2023, Peik wrapped up a meeting and headed to his lab, where he was surprised to walk into a room full of excited colleagues. Finally, after decades of searching, they had found the right energy to drive the transition. "It's a rare event in the life of a researcher where you really see something for the first time," he says. "That's a great experience." Hudson's group soon found the correct energy, too. "They beat us by a little bit, but that's OK," says Hudson. "It's an exciting time for everyone."

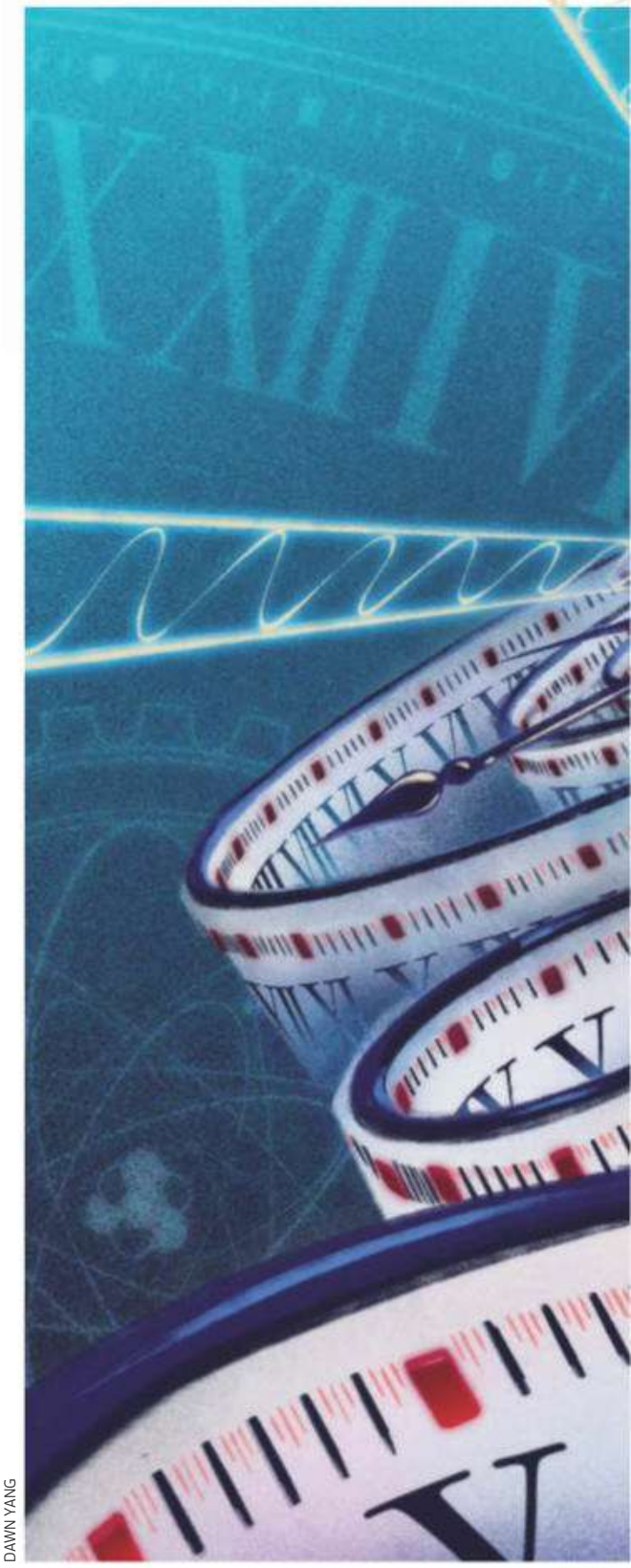
With this huge hurdle cleared, the only step left to making a usable clock was to boost the resonance signal from the nucleus of Th-229, which was still too weak. To get a usable signal for a working clock would require a laser much more sharply tuned at exactly the right energy. In late June, Jun Ye at the JILA research institute in Boulder, Colorado, and his group revealed that they had constructed just such a laser. "Seeing the direct frequency measurement sent a chill to my body," says Ye.

In their paper, Ye and his team describe their set-up as amounting to a nuclear clock, but not everyone agrees. "Jun has made spectacular progress," says Peik, but it doesn't quite meet the definition of a clock. "A clock is a device that shows time," he says. "It should be able to provide a ticking at a well-controlled frequency and to do so for a reasonably continuous period."

While Ye's set-up isn't stable enough to meet this definition, since it worked only for a limited number of cycles, it has proven useful as a tool for probing questions in fundamental physics. "It's the dawn of precision metrology for nuclear physics," says Ye. For his first experiment with the device, Ye and his team used it along with a strontium atomic clock to measure something called the nuclear electric quadrupole moment inside a Th-229 atom, a measure of how symmetrical the charge is within a nucleus, which naturally has a shape like a stretched sphere.

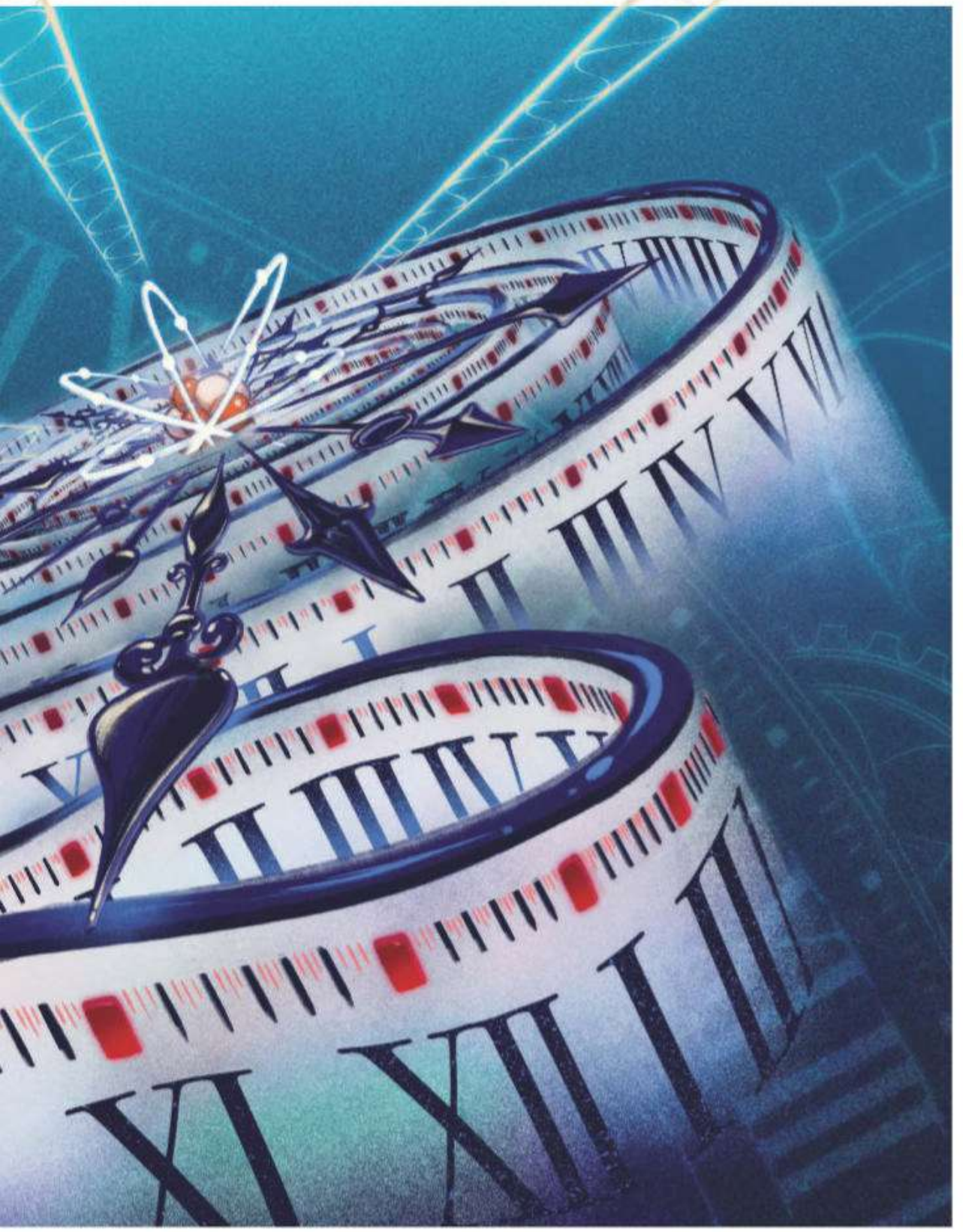
The team hoped to find out if the quadrupole moment changes slightly when the nucleus moves to a slightly higher energy state. Peik's lab ran a similar experiment in 2018, and no such changes were detected. But Ye's lab found a tiny change of 1.8 per cent. "No one has ever been able to observe this experimentally," said Kraemer. "That's a really very big step forward."

Ye and his colleagues used the shifting quadrupole measurements to show that a property called the nuclear volume of Th-229, which is related to the shape of the nucleus, must be altering too. They discovered that the minuscule shape shifts can be used to



DAWN YANG

"A nuclear clock would, in principle, only drop a second every 300 billion years"



The clock that hunts dark matter

Nuclear clocks could be a surprisingly useful tool in the hunt for dark matter, the mysterious stuff thought to make up more than 80 per cent of all the matter in the universe. In particular, these clocks, which are currently being developed (see main story), might be sensitive to a specific candidate known as ultralight dark matter.

Dark matter is only known to interact with other matter gravitationally, making it notoriously hard to detect. But some models predict that ultralight dark matter could disrupt a nuclear clock through the strong nuclear force. If physicists could detect this happening, it would provide evidence that ultralight dark matter exists.

determine the sensitivity of the nuclear transition frequency to a universal constant known as the fine structure constant.

This research relates to an overarching question in physics to do with these universal constants, which are observed values – like the strength of the various forces – that define how the universe works. The tiniest change in any of these constants would have an impact on everything from subatomic physics to cosmic structures. The question is: have these values really always been the same? "You think about nature, how many things areactually constant?" says Hudson. "Everything is dynamic at some level."

Nuclear clocks are the best bet to answer this question. Researchers could construct a nuclear and an atomic clock – one ruled primarily by the strong nuclear force and the other by the electromagnetic force – and let them tick, looking for subtle changes in how they keep time. Any differences could be traced back to teensy shifts in nature's constants, such as the fine structure constant. Others hope to use the clocks to answer other questions too (see "The clock that hunts dark matter", above).

There are plenty of applications in tech, too. Unlike the electrons in an atomic clock, which repel each other, the functioning of neutrons in a nuclear clock is unaffected when the atoms are packed densely together. This means a nuclear clock based on Th-229 atoms could be far more stable than an atomic clock, because the large number of atoms would average out the noise inherent to such systems. This means the clock would be a good candidate for next-generation GPS satellites, as such traits are required to make very precise measurements of location. "The atomic clocks in GPS satellites are nowhere near as good as what we have in the lab," says Hudson, who also points out that nuclear clocks are portable and can run at any temperature.

Eventually, nuclear clocks could be used to redefine time. Currently, a unit of time is based on the rate of oscillation of an electron between two electron shells inside a caesium atom, and it hasn't changed since 1967. But perhaps in future, the second could be defined according to neutron oscillations. "It takes a long time for standards to change," says Hudson, "but I imagine a [thorium-based] clock will eventually be the standard."

There's just one fly in the ointment: Th-229 is incredibly scarce. Because of its radioactive decay, it can't reliably be found in nature. Today's stockpile is a byproduct of nuclear weapons programmes that ended in the 1990s, leaving only 40 grams of high-quality Th-229 on Earth. Kraemer says CERN could produce more, but the facility isn't ideal for manufacturing large quantities. "On the other hand, the amount needed is also rather low," he says. A recent experiment only needed 0.17 micrograms, so today's supply could potentially enable around 200 million nuclear clocks. It is certainly enough to get started. ▮

Lyndie Chiou is a freelance writer based in San Francisco, California

"Now we can get at information we didn't even realise was preserved in dinosaur fossils"

Reconstructing dinosaurs can be a challenge, but working out their behaviour takes that to a whole new level, as **David Hone** tells Colin Barras

DINOSAURS dominated the land for around 180 million years. Yet we have little idea what life was like for these prehistoric icons as interpreting fossils that are at least 65 million years old is fiendishly difficult. Finding out more had long seemed impossible. No longer.

In the past few decades, new technologies and new specimens have provided previously unimaginable windows into their behaviour and ecology. This, along with insights from living animals, is finally allowing palaeontologists to build a picture of dinosaur life ranging from parental care, migration and hunting styles to communication, sociality and combat.

David Hone is one of those working to glean more about life in the age of dinosaurs. A palaeontologist at Queen Mary University of London, he has collated the latest findings into a forthcoming book, *Uncovering Dinosaur Behavior: What they did and how we know*. He gave *New Scientist* a taste of what has been discovered, from migrating herbivores and semi-aquatic predators to why ostriches are a problem for understanding which dinosaurs doted on their young.

PAUL RYDING/JOSEPH WOODHOUSE

Colin Barras: Some of the largest dinosaurs – sauropods such as *Diplodocus* or *Brachiosaurus*, for example – were nothing like any living animal. How do you even begin to work out how they behaved?

David Hone: One of the most important things we can do as palaeontologists is use our understanding of modern animal ecology and behaviour in a much better way. Mouth shape is a good example. If you've got a small mouth, you are usually targeting individual buds or leaves – high-nutrition foods. If you have a very broad mouth, you are usually bulk feeding. That's a simple observation we can apply to sauropods. But I think we have the real potential to go much beyond that.

Could you provide an example?

Well, we have moved away from simply saying "this sauropod was very big, so it probably moved slowly". We are now beginning to realise that some of these slow animals were actually relatively energy efficient, meaning they could travel long distances – even if it took them a long time. That opens up new questions. Why might a sauropod travel a long way? An obvious reason might be that it's in search of food. Can we test that? Well, yes: we can study the chemical isotopes in sauropod teeth and see a recurring signature reflecting their diet that tells us an animal was shifting between two spots every six months. That's an annual migration. Then we can begin asking how that ties in with our reconstructions of the local ecology at the time to understand the drivers of migration. Or we can begin asking how this migration might have affected the behaviour of the predators in the region. We've gone from "big sauropods moved slowly" to something far more sophisticated.

Can we infer from this that all or most of these gigantic sauropods were migrating animals?

You have to be careful: we know from today's animals that behaviour is astonishingly flexible. Wildebeest are a great example. To many of us, almost the defining feature of these animals is the mass migration they make across the Serengeti and Masai Mara. But go to South Africa and the wildebeest there don't really migrate. It's the same species behaving in a completely different way. That tells you the mass migration behaviour seen in the Serengeti isn't tied to the biology of ›

"We can see growth rings on the teeth of embryonic dinosaurs"

these animals, it's entirely environmentally driven. The same must have been true for at least some dinosaurs.

That's important to know because there are implications for other aspects of behaviour – behaviours like parental care. If you're constantly moving, it's more of a challenge for offspring to keep up. But if you are relatively stationary, it's possible to protect young offspring. Today, lots of people are very happy with the idea that many of these dinosaurs showed extended parental care. We actually have very good data for that.

You mean dinosaurs like *Maiasaura*, where fossilised nests appear to show hatchlings were fed on vegetation brought back by their parents?
Yes, that nest study was really fundamental research – although, of course, it only tells us about the behaviour of one dinosaur species at just a handful of sites that have fossilised. It's not a model for all members of that group, let alone all dinosaurs.

Another surprising idea is that some dinosaurs were semi-aquatic. What do you make of research suggesting that the giant theropod *Spinosaurus* was a crocodile-like predator?
Those ideas don't always stand up to scrutiny once you look at all the available information and think through all the implications. For example, it was argued that *Spinosaurus* could sit in the water like a crocodile with just the eyes and nostrils above the water, but the nostrils are on the side of the head, not the top, and the eyes aren't any more raised up in these dinosaurs than others. In fact, they're rather lower than in many, so it really doesn't match the available data.

These days we know that birds are living dinosaurs. Does that mean we can enhance our understanding of prehistoric dinosaur behaviour by studying birds?
People are doing this now, but it's really important to be sure you understand modern bird species before you begin making inferences. For example, in birds, there is a complex interchange between the number of eggs laid, how big the eggs are and how much care the parents give the hatchlings. But then you have ostriches. Now, ostriches are very, very annoying in this context, because a successful male will court a number of females and they will each come and lay a few eggs in his nest. Was that true of some dinosaurs? If so, then if you find a dead dinosaur on a nest of 50 eggs, you don't know whether that reflects the output of one female or 10. So, ostriches tell us it's not enough to simply say: I have this many eggs in the nest that were laid by one animal, which cared for the offspring.

How are new tools and technologies transforming our understanding of dinosaur behaviour?
With new techniques we can get at information we didn't even realise was preserved in dinosaur fossils. But it doesn't necessarily lead to easy conclusions. A great example is using CT scans to look at dinosaur embryos. We can see growth rings on the teeth of these tiny animals that were deposited daily. That's astonishing to begin with, but you can then use those growth rings to work out how long the embryos remained in the egg. When people did this for two plant-eating dinosaurs, *Protoceratops* and *Hypacrosaurus*, it turned out they had an extraordinarily long incubation time. We're talking up to six months, when you might have expected this to be more like weeks or a couple of months.

That blows some of our assumptions out of the water. What were the parents doing? All of the options look weird. Alligators will guard a nest for a couple of months, but I honestly can't easily imagine a dinosaur hanging around for six months to guard its nest, which would be difficult without food being available. But completely abandoning the nest is not necessarily something I would expect them to do either. Then there's the possibility that they abandon the nest for a time and then come back to it to look after the babies when the eggs hatch – but that's almost unprecedented among today's animals.

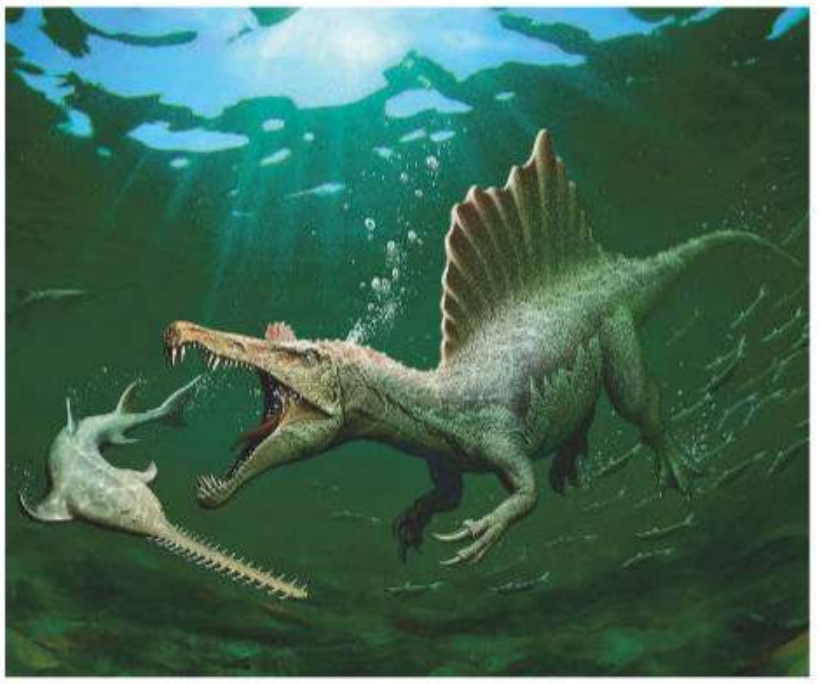
So, basically, none of the options are clear. But, of course, you'd rather know about that problem. The alternative is being mistakenly confident in assumptions that are actually wrong.

Are there other instances where we have to be careful not to make assumptions when using new technology on specimens?
Colour is a perfect example. With new imaging techniques we can spot pigment-containing melanosomes that are in

Some sauropods made an annual migration

MARK GARLICK/SCIENCE PHOTO LIBRARY/GETTY IMAGES

JULIUS T CSOTONYI/SCIENCE PHOTO LIBRARY



MOHAMAD HAGHANI/ALAMY

The plumage colours of *Anchiornis* (above) and other feathered dinosaurs hold clues about their behaviour

Some dinosaurs, including *Spinosaurus* (left), may have been semi-aquatic

fossil feathers and work out their colour.

This technique has been applied to feathered dinosaurs like the small Chinese predator *Anchiornis*. It told us that one individual had black and white feathers on its wings and a rusty-red coloured head. But this is just one animal when it died.

Modern birds tell us that there might have been more going on. Look at the grouse: babies look different to adults, males in the breeding season look different to females, and in winter both males and females living at higher altitudes or latitudes turn white for camouflage in the snow. So, yes, it's wonderful we've worked out what one *Anchiornis* looked like at the time it died. Now we have to do it again with 50 or 100 *Anchiornis*.

I guess that study isn't possible because we just don't have that many fossils?

But we do. I've been to a collection in eastern China that had the thick end of 1000 specimens of *Anchiornis*, and about one-third of them had feathers. Most of those are probably going to have melanosomes. Analyse 300 of them and you will learn so much more about the ecology and behaviour of this dinosaur – especially if you combine that with information from other techniques, such as analysing stable isotopes to find out which specimens died in winter and which died in summer, and examining bone microstructure to see if you can work out which were male and which were female. For example, if males show bright colours and females don't, this would likely tell you something about their courtship and also rearing behaviours: unornamented male birds usually help raise chicks. And if they are both showing camouflage patterns year-round then they might well have been very vulnerable to predators.

People love to hear about new or unexpected discoveries about dinosaur behaviour, but is it a problem that today's super-realistic dinosaur nature documentaries often feature the more speculative ideas?

Well, if those documentaries just showed the things we definitively knew that dinosaurs did, then they would be very short. From my perspective, as long as some good information is communicated and people start to understand things, then I'm comfortable. I think there is a general accumulation of good information. For instance, it's now normal not just to show feathered dinosaurs, but to show feathered dinosaurs with the right kind of feathers in the right places and being used in ways that we think they were used. That's something that has happened in big-ticket documentaries only within the past 10 years, and the idea of dinosaurs with feathers is probably now beginning to stick in the public's mind. So, I do think the documentaries are moving in the right direction. ▮

Colin Barras is a freelance science writer based in Ann Arbor, Michigan

NewScientistLive

Hear more from David Hone at this year's New Scientist Live. He will be speaking on 13 October about how dinosaur researchers interpret the often minimal and even conflicting information available to them

For more information, visit
newscientist.com/nslmag

The back pages

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Mathematics of life

Go with the flow

Katie Steckles enlists the help of fluid dynamics researcher **Kat Phillips** to explain the maths of pouring wine

Katie Steckles is a mathematician, lecturer, YouTuber and author based in Manchester, UK. She is also adviser for *New Scientist*'s puzzle column, BrainTwister. Follow her @stecks

HAVE you ever found yourself dispensing wine from a box, or beer from a standing keg, and wondered how much liquid is left in the container? If you were thinking about it like a mathematician, you might have noticed that the fuller the keg is, the faster the beer comes out.

This might seem obvious, but this is a known mathematical relationship, and it uses a versatile piece of maths that crops up in many other real-world situations. Fluid dynamics is the study of flow: how liquids and gases behave under forces and interact with their environment, which we can model mathematically. Bernoulli's principle tells us that for a given particle of fluid, the total sum of its energy and pressure remains constant as it moves through space.

This means the sum at one point must match the sum in another location along the same path. For a typical fluid like air or water, the quantities involved are pressure, and energy in two forms: potential energy (height) and kinetic energy (velocity). If we keep one of these values fixed, the other two will then have a proportional relationship, which we can take advantage of.

In the case of a wine box, there will be a path that the wine moves along that connects the top of the liquid's surface inside the box, through to a point just past the spout where the liquid flows out. As both of these points are touching the surrounding air, we can say that their pressures

SHUTTERSTOCK/OLESCHWANDER

are roughly equal. Bernoulli's principle then gives a relationship between the height difference and the speeds at these two points – namely, the more wine that is left in the box, the greater the height difference between the two points and the faster the fluid will come out of the spout.

The same maths can be useful when you want to open a light plastic bag – like a trash bag – but find it is sticking together. The best trick is to open the bag a tiny amount, and then quickly blow some air into it from a few centimetres away. This quick change in speed, with no change in height, creates a region of low pressure in front of the opening of the bag – which will cause air nearby to rush away from the high pressure and towards the low pressure, filling it up.

This same idea works in any situation involving fluids – where one of the three variables of height, pressure and speed is fixed, the other two will be related. Even the flight of an aeroplane can be modelled in the same way: the curved shape of plane wings is designed so that the air above them moves faster than the air below. This creates a region of low pressure above the wing that produces suction to lift the aeroplane higher into the sky.

So you can thank Bernoulli's principle next time you pour a drink – maths is there to keep everything flowing smoothly. ▮

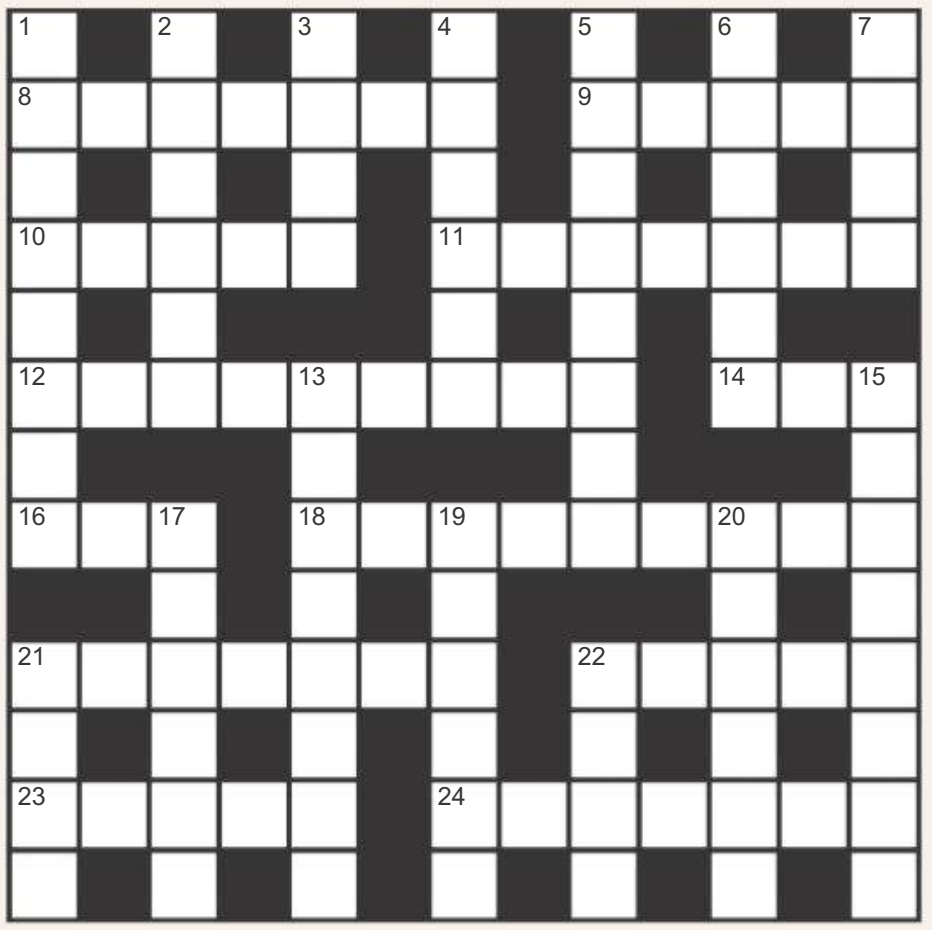
These articles are posted each week at newscientist.com/maker

Mathematics of life appears monthly

Next week

Debunking gardening myths

Cryptic crossword #144 *Set by Rasa*



Scribble zone

Answers and the next quick crossword next week

ACROSS

8 Those going around at CERN owned golf clubs, all but one (7)
9 Male captivated by Shakespearean villain's winged form (5)
10 Drops rules for the auditor (5)
11 Fatty hummus, say, fills a hole at short notice (7)
12 Company given false hopes after YouTube turns over new leaf (9)
14 Looking back, cross block (3)
16 Pair moving west? That's a drag (3)
18 Underground Alaskan city's timekeeper (9)
21 Carelessly uncrate hybrid creature (7)
22 Faint after initially tolerating small adjustment (5)
23 Horse-drawn vehicle circling a unit (5)
24 Possibly "dewiest" or another description for eyes? (4-3)

DOWN

1 Spooner's tribunal closed timesaving route (8)
2 Aimless commercial break (6)
3 Ways of working on small natural carpet (4)
4 Without hesitation, I bad-mouth Easter or Christmas (6)
5 Pastry containing peeled lime, not cooked pepper (8)
6 Canadian dictionary somehow crossed the pond (6)
7 Amount of a chemical agent (4)
13 Berate graduates carried in after hours (8)
15 With extra energy, markets wildly adorable mammals (8)
17 Cold attempt to sustain success... (6)
19 ...really confused chair, we hear (6)
20 Scandinavian city officials, at first, like gold (6)
21 Toxic gas around narcotic shrub (4)
22 Orderly is extremely touchy about credentials (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #269
set by Bethan Ackerley

1 What is the chemical formula of lactic acid?

2 In botany, plants with adaptations to live in arid places are known as what?

3 X chromosomes that have been rendered inactive via Lyonisation are typically known as what?

4 What is the Ramanujan number, i.e. the smallest number that can be expressed as the sum of two positive cubes in two different ways?

5 Which of Saturn's rings is the brightest?

Answers on page 47

BrainTwister
set by Mary Ellis
#37 Digital multiplication

Consider the following rule: Start with any two-digit number, then repeatedly multiply the digits together until the result is a one-digit number. For example: 84⇨32⇨6, or 97⇨63⇨18⇨8.

What happens if you start with 93?

There is just one sequence of length 5 starting from a two-digit number. This sequence ends with the number 8. What must the starting number be?

Can you find the longest possible sequence starting from a three-digit number?

Solution next week

Stop all the clocks

What would happen if time stopped?

Pat French
Longdon-upon-Tern, Shropshire, UK
Nothing. (Lots of it). Time is a dimension. Without time, existence would cease.

While it takes some sort of brain and memory to be aware of time passing, every particle in the universe exists in space-time. There would be nothing in which they could move or even "be". Also, every force is exerted over time. This means the forces that hold the universe together, from gravity to the weak nuclear force (which holds together the quarks in protons and neutrons), would have no time in which to act. The question is like asking what would happen if "size" stopped.

Peter Holness
Hertford, UK
The interesting thing about this question is that it teeters on the edge of "admissibility". Scientists usually try only to ask themselves admissible questions. It has become more acceptable recently for physicists to speculate whether

"It has become more acceptable recently for physicists to speculate if time even exists. If it doesn't, the question is inadmissable"

time even exists. If it doesn't, the question is inadmissible. But it is admissible if it does.

Time's existence is broadly accepted in how we measure and "synchronise" our lives to it. We also use it as a variable in our equations. But "change" is one of the few things we can be absolutely certain of. Historically, measuring time involves accurately "chopping it up" into ever smaller "chunks", from the sun's rising and setting to the "ticking" of atomic clocks.

But physics has a big problem in agreeing how time is understood between quantum mechanics and general relativity, and this makes answering the reader's question very difficult.

The latter theory has much to say about how high speeds, massive objects and gravity warp time. Perhaps we can say two things: stopping change stops time and vice-versa. And an "observer" might experience "stopped time" inside a black hole but would be destroyed in the process.

Andrew Taubman
Perth, Western Australia
Time is the space between events (broadly defined). If time were to stop, there could be no more events, so the answer is "nothing". Or, as early 20th-century author Ray Cummings wrote, "Time... is what keeps everything from happening at once".

Nick Canning
Coleraine, County Londonderry, UK
A misleading picture of time haunts this question, one visualised in those movie scenes of "frozen moments" where a camera viewpoint travels 360 degrees around a space apparently frozen in time. These are uncanny because they are physically impossible for an observer to experience. (They are obtained by using multiple space-separated cameras at the same time.) If time stopped for all space-separated observers, then literally nothing could ever happen. But this is physically impossible except at a space-time singularity such as at the classical big bang.

Albert Einstein's special theory of relativity enables me to deduce that time would stop for you if you could travel past me at the speed of light in a vacuum (but you have inertial mass, so this is impossible). You wouldn't experience time to have stopped, but would say it was my clock that was stopped, emphasising that there is no such thing as absolute time applicable to all observers.

An observer outside the event horizon of a black hole would also see time stop for someone falling into it, forever unable to cross the boundary. But the unfortunate traveller wouldn't experience any slowing of their own clock and could fall through without noticing, provided the black hole was large enough that tidal forces didn't "spaghettify" them before they crossed the horizon.

John Elliott
Stockport, Greater Manchester, UK
Many questions about the nature of time are complicated by hidden illogicalities. For example, the two words "happen" and "stop" each contain hidden references to time and only have meaning if it exists. Without time, nothing can change, nothing can happen, nothing can start or stop. So how should we think about time? Physics has given us some very useful clues.

Perhaps the best clue is that most fundamental and simple of constants, the speed of light or c, which is equal to 2.998×10^8 metres per second. This is known to be a universal constant, the same throughout the universe, at all times, and the same for every observer, whatever their circumstances. You can't get more fundamental than that. But note that c is a speed, which has the dimensions of length divided by time. Thus, as soon as we define a spatial unit of length, c also automatically defines a unit

IFEELSTOCK/ALAMY

Might we all be programs in a powerful supercomputer?

This week's new questions

Red or blue pill? **Is there any scientific evidence disproving the notion we are part of a vast simulation run by an advanced civilisation?** ***Philip Simmons****, Culver City, California, US*

Pointed question **Why do animals like rhinoceros and triceratops have horns while deer and elk have antlers?** ***Colin Oatway****, Wokingham, Berkshire, UK*

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Tom Gauld
for New Scientist

LOOK! HE'S ADDING AN EIGHTH COLUMN. THAT MUST BE FOR US!
I III IV V VI VII
B C N O F
Si P S Cl
Ti V Cr Mn
As Se Br
Y Zr Nb Mo
In Sn Sb Te
La Ta
Tl Pb
EARTH, AIR, FIRE AND WATER WAIT EXCITEDLY TO SEE HOW THEY'LL FIT INTO DMITRI MENDELEEV'S TABLE OF ELEMENTS.

of time, the time taken to travel that length unit at velocity *c*. So, time is a "given" at the heart of all reality, as is space.

This neatly leads us to the Minkowski view of space and time: we live in a four-dimensional space-time, where three of the dimensions are the space we are familiar with, each of which can be measured in metres. The fourth dimension can also be measured in metres, but we are travelling along it at the velocity *c*, the speed of light, and we interpret that as the world changing, and that gives us the concept of time. Time doesn't "flow"; it is just us shooting along that fourth-dimensional axis. The section we have just traversed is the past and is fixed, immutable; while the section ahead is the future and is uncertain, described only by a series of probabilities or possibilities, over which we have limited control.

Malcolm Afferson
Barnsley, South Yorkshire, UK
Nothing. Until someone's tummy rumbled. Then someone else would look at their wrist and suggest that it was lunchtime.

"Stainless steel tends to degrade in seawater because chloride ions allow corrosion of the underlying metal, often forming pits"

Cleaning up

I have a stainless steel kitchen sink. When I clean it with bleach, leaving it instantly gleaming, what happens to the particles that were staining it?

Mark Dirnhuber
Bristol, UK
Stainless steel has chromium as the key ingredient: on contact with air (or even nitric acid) this forms a thin but resistant surface layer of chromium(III) oxide (Cr_2O_3), which protects the steel from further corrosion. This oxide layer may well pick up stains, for example from tannins, which are polyphenols from tea.

Bleach is sodium hypochlorite (NaOCl) and is a strong oxidising agent, which is alkaline and also contains free chloride anions (Cl^-).

Chloride ions disrupt the protective layer and eventually allow corrosion of the underlying metal, often forming pits: this is why stainless steel tends to corrode in seawater.

The hypochlorite can oxidise Cr(III) to Cr(VI), for example to chromate, e.g. $[CrO_4]^{2-}$, and also Fe(II) or (III) to Fe(VI) as in ferrate $[FeO_4]^{2-}$. If a little bleach is added to some ferrous sulphate or ferric chloride solution, once the precipitate has settled, the pink colour of the liquid above is visible due to the ferrate.

Hypochlorite bleaches tannins by disrupting the ring structures in the molecules, decolourising and solubilising the stain. It will also attack and dissolve protein films on the steel. By rinsing and exposing to air, you may well be refreshing the oxide layer.

Personally, my choice would be to forgo all this dubious chemistry and rely on detergent and elbow grease. ▮

Answers

Quick quiz #269 *Answers*

1 $C_3H_6O_3$
2 Xerophytes
3 Barr bodies, or X-chromatins
4 1729
5 The B ring

Quick crossword #166 *Answers*

ACROSS 8 Eye tooth, **9** Adhere, **10** Spirit, **11** Sediment, **12** Scirocco, **13** Unsafe, **14** *Back to the Future*, **18** Cosmic, **20** Racemose, **23** Teraflop, **24** Glands, **25** Bisect, **26** Speculum

DOWN 1 Myopic, **2** *Star Trek*, **3** Aortic, **4** Physiotherapist, **5** Dandruff, **6** Thymus, **7** Transfer, **15** Anorexia, **16** Osculate, **17** Tympanum, **19** McAfee, **21** Cygnet, **22** Sodium

#36 Prime generators *Solution*

Setting p = 5 generates four primes (5, 7, 11 and 17).

There are three prime numbers between 220 and 230 (223, 227 and 229), and setting p = 227 generates a sequence of four primes (227, 229, 233 and 239).

For $x^2 + x + p$, setting x = 0 gives $0^2 + 0 + p = p$ and setting x = 1 gives $1^2 + 1 + p = p + 2$, thus generating a twin prime pair (p, p + 2).

Lipstick in the brain

Lipstick interacts with the human brain mostly in indirect ways. Kazue Hirabayashi and colleagues have been modernising the search for some of those interactions.

Their stated goal is to find "a real-time brain-based product evaluation method which detects the incongruency between a product, in this case lipstick, and a consumer's expectations". The latest explorations led to a study called "Right prefrontal activation associated with deviations from expected lipstick texture assessed with functional near-infrared spectroscopy", published in *Frontiers in Neuroergonomics*. Reader Nicolas Clairis brought it to Feedback's attention.

The experiment tried to measure the incongruency – the presumably disappointing mismatch – between the actual softness of a lipstick and the softness the lipstick customer had expected of that lipstick. The method being tried here was fairly novel for the cosmetics industry: using functional near-infrared spectroscopy (fNIRS) to measure activity in a lipstick-wearer's right inferior frontal gyrus.

Some members of the team had done earlier explorations – also using fNIRS – of lipstick in the brain. In 2021 they reported discovery of "a willingness-to-pay associated right prefrontal activation during a single, real use of lipsticks".

Four years earlier, they reported an even more ambitious project. Its broad scope is evident in the title: "Evaluation of pleasure-displeasure induced by use of lipsticks with near-infrared spectroscopy (NIRS): usefulness of two-channel NIRS in neuromarketing".

Feedback has seen few better examples of lipstick-and-brain-centric interdisciplinary research.

Face value of lipstick

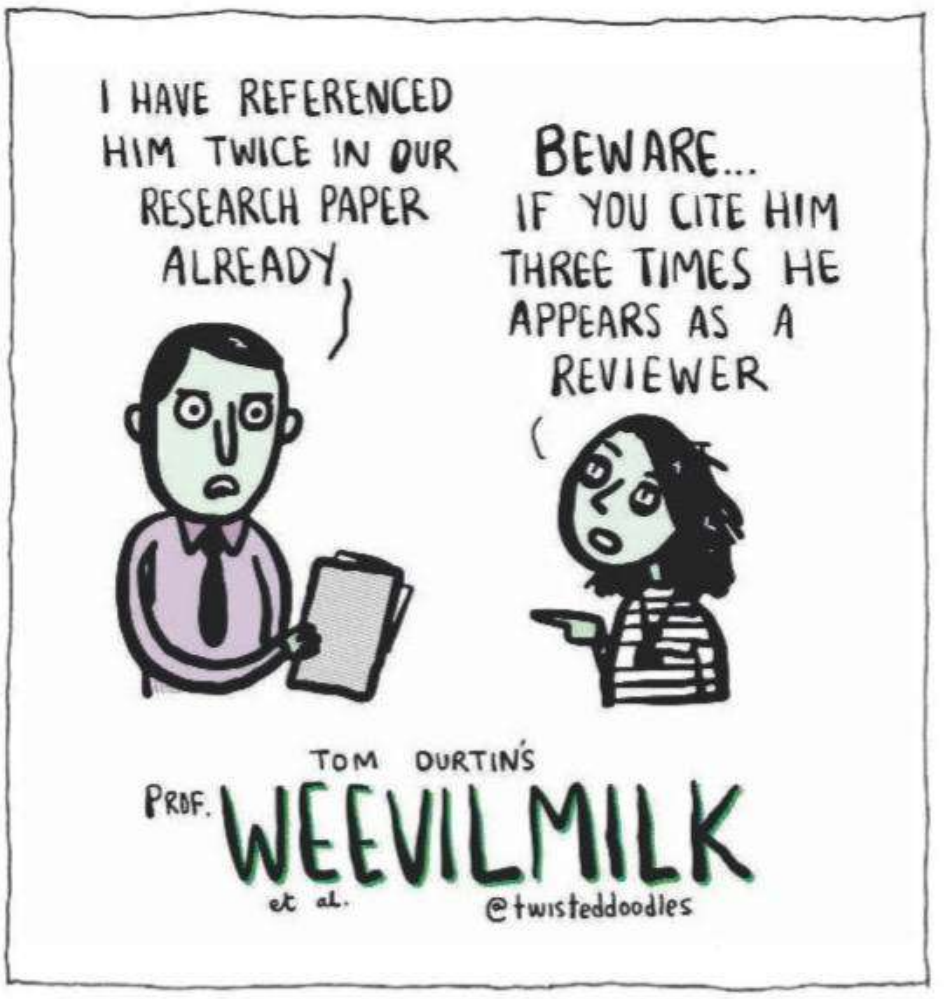
But here is perhaps one better example of lipstick-and-brain-centric interdisciplinary research: a study by Dhuha Hadiyansyah, Era Bawarti and Maria Ulfa at the Al-Azhar University of Indonesia.

The trio sought to determine how female students at the university "represented particular meanings through their choice of lipstick colours". They report a contrast – an incongruity – between the students' explicitly stated reasons for choosing colours and "the subconscious message they want to convey".

That subconscious message, explain Hadiyansyah, Bawarti and Ulfa, "is quite complex, ranging from optimism, cheerfulness, joy, modesty, warm [sic], wanting to be the centre of attention, femininity, passion and love, to sensuality".

The study, "Lipstick as female students visual communication strategy", was presented at the 4th International Conference on Islamic Epistemology, which was conducted virtually. The published version contains no information as to lipstick-borne conscious or unconscious messaging by conference participants.

Twisteddoodles *for New Scientist*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What a buzz

This bounty year for cicadas (see "A cicada double brood is coming – it's less rare than you think", newscientist.com/article/2427004) has Feedback remembering a medical experiment that used cicadas to treat tinnitus.

Those with tinnitus hear annoying sounds at times and in places that people who don't have tinnitus don't. The sounds can vary from person to person, from day to day, even from moment to moment. Descriptions of them, when listed, sound like a chunk of a Foley artist's to-do list: ringing, whining, blowing, roaring, buzzing, chirping, clicking, sizzling, crackling, white noise, static and so on and on and on.

Commonly, people say it is like the sound cicadas make.

And so, decided Mithila Durai and Grant Searchfield at the University of Auckland, New Zealand, why not use the fight-fire-with-fire approach? Fight tinnitus with cicadas – or, for efficiency and ease, recorded cicada sounds.

So they did. They tried other recorded sounds, too: surf and rain, and also some artificially generated noise. The treatments continued over several weeks. In 2017 they published a paper, in the journal *Frontiers in Aging Neuroscience*, about this "mixed-methods trial of broad band noise and nature sounds for tinnitus therapy".

None of it cured tinnitus. But some sounds – especially the cicadas – helped some people sometimes, lessening the intensity or the annoyance of the tinnitus. Or so the scientists say those people said. Alas, there is no technically sound way to directly measure the perceived sounds caused by tinnitus. The only available evidence – what people say they hear, is a second-rate kind of evidence. It is pure hearsay.

Measured policing

Feedback's search for hiring restrictions specifying numbers that aren't based on actual job-performance requirements stirred memories for reader David Curtis. He writes about some history in his country, Australia.

"Your request for job requirements based on measurements bring to mind an ad from the 1970s to increase female participation in the police forces. A picture was shown of a male and female in uniform asking the question 'What is the difference between these two police officers?' The answer was given as '6 inches'."

Human memory is impressive, but notoriously unreliable. Feedback hasn't verified the persuasiveness or the existence of this ad, or the precision of that measurement.

Marc Abrahams

The art and science of writing science fiction: Brecon Beacons, Wales

8 November 2024 | 3 days

Take your science fiction writing into a new dimension during this weekend devoted to building new worlds and new works of art. Join *New Scientist* comment and culture editor Alison Flood, along with author and former *New Scientist* editor in chief Emily Wilson, for an immersive writing weekend. Explore the world of science fiction and learn how to craft your own captivating sci-fi tales.

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Whether you are a seasoned writer, just starting your writing journey or are an avid science fiction enthusiast interested in learning how the craft works, this weekender is the perfect launchpad for your sci-fi dreams. You will come away from the weekend with:

- Training on how to craft compelling science fiction stories.
- Insight into how top science fiction authors write their novels.
- A new cohort of fellow writers.

The weekender will be based at Craig Y Nos Castle in the Brecon Beacons (Bannau Brycheiniog), a unique Grade II* listed hotel and venue housed in a fully restored 1840s gothic castle. The castle sits alongside the upper river Tawe on the edge of the Black Mountains and was owned by 19th-century opera singer Adelina Patti.

Weekend highlights include:

- **Learn the key elements of worldbuilding, character development and plotting from established authors.**
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- **Meet *New Scientist* staff, science fiction experts and fellow *New Scientist* readers.**

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